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JOHN M. CLARKE, Director

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NATIONAL MUSEUM

THE GEOLOGICAL HISTORY OF NEW YORK STATE

BY

WILLIAM J. MILLER

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Taughannock Falls (height 215 feet) which ranks as the highest true waterfall in New York State. Located near Trumansburg, Tompkins county. The rocks are Devonian sandstones and sandy shales and the postglacial gorge just below the falls is nearly 400 feet deep.

Photo lent by H. R. Head, Ithaca, N. Y.

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THE GEOLOGICAL HISTORY OF NEW YORK STATE

BY

WILLIAM J. MILLER Ph.D.

PREFACE

The researches and truths of any modern science, if they are properly to fulfil their mission, should be brought within the reach of laymen. In this bulletin the purpose is to present in a simple, readable form, an outline of the wonderful story of the physical development of New York State. No knowledge of physiography or geology is presupposed. Any person possessed of ordinary intelligence and a willingness to learn is fully prepared to read these pages. When the reader has gained a fair understanding of the principles here set forth, he will be much better prepared to use intelligently the publications of the New York State Museum which deal with the geology and geography of many portions of the State. In short, this volume may be considered as a "first book" for all who are interested in the physical features of the State, and it is believed that teachers and older pupils in geography and physical geography may receive helpful suggestions from it.

It must be clearly understood that scarcely more than a sketch of such a large subject can be given in so brief a space. Local details can seldom be brought in except for illustration of certain important points, and of necessity many questions will occur to readers interested in the natural features of their home regions which are not directly answered. It is hoped, however, that most of the important and striking geographic features in all parts of the State are explained, and that many local details will find ready explanation by the application of the principles set forth.

Emphasis is here placed upon the genesis of geographic forms. It is one thing merely to state a geographic fact, such as the location of a mountain or lake or valley, but it is a far different thing to explain how the mountain or lake or valley came to be there. Every geographic form has a history, and if we fail to appreciate that history we lose the most interesting and valuable part of our geographic training. Geographic facts, like all others, are more easily understood and remembered when the reasons for their existence are given, yet it must be admitted that the teaching of such rational geography is still in its infancy in the schools of the State.

The use of a certain number of scientific terms is unavoidable in practice, but common terms only are employed and in every case these are carefully explained when first used in the text. Particular attention is directed to the photographs, maps and diagrams, all of which have been carefully selected or made for the express purpose of illustrating this text. Except for some quotations, references to original papers have been omitted, but at the end of the volume a list of the more important books and papers of general interest is given, and anyone desiring to broaden into wider fields or greater details can do so readily with the aid of those references.

I have used many personal observations made during travels into almost every county of the State, but obviously the book could never have been written were it not for scores of devoted men of science who, during the last hundred years, have zealously labored to unravel the natural history of the great Commonwealth. I gratefully acknowledge my indebtedness to them all.

I am under particular obligation to Dr J. M. Clarke, our able and efficient State Geologist and Director of Science, for his kindness in critically reading the manuscript and making important corrections and suggestions.

W. J. Miller

Hamilton College, Clinton, N. Y.

PREFACE TO THE SECOND EDITION

During the ten years since the publication of the *Geological History of New York State,* there has been notable advance in the acquisition and interpretation of the geological records of the State.

Public demand for this book justifies a second edition and Professor Miller has revised it in accordance with present knowledge. The general arrangement of the first edition has not been materially changed.

John M. Clarke,
Director

June 1924

Chapter 1

INTRODUCTION

GENERAL PRINCIPLES AND REFERENCE TABLES

Few states present a more wonderful variety of physical features or afford a more excellent opportunity to those interested in the study and teaching of geography or geology than does New York. Here are rock formations of all the more important types; all the leading types of mountains (Adirondacks, Catskills, and Taconics) except actual volcanoes, though lavalike rocks occur in the Adirondacks and in the Palisades of the Hudson; hundreds of lakes of various shapes and kinds; shore outlines ranging from the great sand bars and beaches of Long Island to wave-worn cliffs along the shores of Lake Erie and Lake Ontario; typical prairie plains like that south of Lake Ontario; a great plateau in the southwestern region; valleys and gorges of varied origin; rivers of all types, often with remarkable histories; a striking display of relief features; and extensive and varied deposits of glacial origin. Accordingly, it is not an exaggeration to say that examples of nearly all the most important physical features of the earth are represented within the borders of this State.

As the observer looks out over the State he sees this great variety of physical features and, unless he has given some thought to the subject, he is very likely to regard these as practically unchangeable, and that they are now essentially as they were in the beginning of the earth's history. Some of the fundamental ideas taught in this book are that the physical features of the State, as we behold them today, represent but a single phase of a very long continued history; that significant changes are now going on all around us; and that we are able to interpret the geography of the present only by an understanding of its changes in the past.

Geology is concerned with the evolution of the earth and of its inhabitants, as revealed in the rocks. This science is very broad in its scope and treats of the processes by which the earth has been, and is now being, changed; the structure of the earth; the stages through which it has passed, and the development of the organisms which have lived upon it.

Geography deals with the distribution of the earth's physical features, in their relation to each other, to the life of sea and land, and human life and culture.

Geography is the outward and present expression of geological effects. The terms geography and geology are thus here used in the sense that the latter includes the former, as the cause includes the effect. *Paleogeography* has reference to the geography of the past epochs in the history of the earth.

Physiography, or physical geography, deals with the configuration (relief) of the earth's surface and how it was produced.

As a result of the work of many able students of earth science during the past hundred years, it is now well established that our planet has a clearly recorded history of many millions of years, and that during the lapse of those eons revolutionary changes in geography have occurred; that there has also been from an early stage of the earth's history a vast succession of living beings which have gradually passed from simple into more complex forms and have, in some particulars, reached their highest expression in the organisms of the present time. The geographic changes and the organisms of the ages gone by have left us abundant evidence of their character and the study of the rock formations has shown that within them we have a fairly complete record of the earth's history.

In the time of Alexander von Humboldt, less than one hundred years ago, the keen student of natural phenomena could carry in his own mind most of what was definitely known of earth history. Today, because of the tremendous growth of the science, it would be a presumption for any man to claim that he knows all that has been learned about the geological history of even the single State of New York. While it is true that much yet remains to be learned of this old earth, it is a real source of wonderment that man, through the exercise of his highest faculty, has come to know so much about it.

All the rocks of the earth's crust may be divided into three great classes: *igneous, sedimentary,* and *metamorphic.*

Igneous rocks comprise all those which have ever been in a molten condition, and of these we have the volcanic rocks (for example, lavas) which have cooled at or near the surface; plutonic rocks (e. g., granites) which have cooled in great masses at considerable depths below the surface; and the dike rocks, which when molten have been forced into fissures of the earth's crust and there cooled.

Sedimentary rocks comprise all those which have been deposited under water (except for some wind-blown deposits). They are nearly always arranged in layers (stratified). These rocks may be of mechanical origin, such as clay or mud which hardens to shale; sand, which consolidates to sandstone; and gravel, which when cemented becomes conglomerate. Or they may be of organic origin, such as limestone which is formed by the accumulation of calcareous shells; flint and chert, which are accumulations of silicious shells; and coal, which is formed by the accumulation of partly decayed vegetable matter. Or, finally, they may be formed by chemical precipitation, as beds of salt, gypsum, bog iron ore, etc.

Metamorphic rocks comprise both sedimentary and igneous masses which have been greatly changed from their original condition. Thus, under conditions of great pressure and heat, with superheated moisture, sedimentary rocks may become crystalline, as when shale is changed to schist, sandstone to quartzite or limestone to marble; or an igneous rock may take on a banded structure, due to a rearrangement of its component minerals, and thus become a gneiss.

To the modern student of earth science, the old notion of a "terra firma" is outworn. That idea of a solid, immovable earth could never have emanated from the inhabitants of an earthquake country. In the San Francisco earthquake, along a line of several hundred miles, one portion of the Coast Range mountains slipped from two to twenty feet past the other. In Alaska, in 1899, a portion of the coast was bodily elevated forty-seven feet. In Japan in 1891, for a distance of forty miles along a rift in the earth's crust, there was a sudden movement of from two to twenty feet. These are merely striking instances of many of the sudden earth movements of recent years. Hundreds of earthquakes occur yearly in the islands of Japan alone, and it is probably true that the earth is shaking all the time.

There are still other movements which are taking place more slowly and quietly, but which are more significant for our interpretation of the profound geographic changes which have occurred during the millions of years of known earth history. Thus the coast of Norway is rising while that of northern France is sinking. Distinct beaches at different elevations far above the ocean level on the western slope of the southern Andes testify to important changes of level in comparatively recent time. A fine illustration of notable sinking of the land is proved by the drowned character of the lower Hudson valley, and also by the fact that the old Hudson channel has been definitely traced, as a distinct trench in the ocean bottom, for one hundred miles eastward from Sandy Hook. That this same region has still more recently been partially re-elevated is indicated by the presence of very young stratified beds of clay and sand which are now raised from seventy to three hundred feet above the river, the elevation increasing northward toward Albany. Actual surveys show that, in the Great Lakes region, a differential movement of the land is now in progress, the elevation being greater toward the north.

In the succeeding pages evidence will be offered to show that most of New York State has been covered repeatedly by ocean water. It will also be established that where such mountain ranges as the Appalachians, Alps or Himalayas now exist was formerly ocean bottom upon which layers of sediment were being spread out. Those layers of sediments have been bent, crumpled, folded, and greatly elevated above sea level. Thus it is literally true that the great typical mountain ranges of the earth have been born out of the ocean.

Among other important processes of nature which have long been active in modifying the earth, are those of *weathering* and *erosion*. Weathering is brought about by the various atmospheric agencies such as moisture, oxygen, carbonic and other acids, together with changes of temperature, and the result is to cause all rock masses to disintegrate or decay. In this way most soils are produced, and were it not for the process of erosion, soils would be much deeper and more widespread than they now are. Weathering prepares the material which is carried away by the streams, and this transported material is deposited either along the flood plains of the lower stream courses or on the bottom of the lake or ocean into which the streams flow. Every stream, at time of flood, is heavily charged with mud or even coarser sediment which has been derived from the wash of the land of its drainage basin. The very presence of the sediment in the streams proves that the land is being lowered and although, on first thought, it may be supposed that no really great change could be accomplished by this means, nevertheless we must remember that nature has practically infinite time at her disposal so that slowly but surely vast geographic changes are wrought and, perchance, a tremendous canyon like that of the Colorado in Arizona will be carved out by weathering and erosion. The general tendency is for all land masses to wear down to or near sea level and, were it not for renewed uplifts, all land, even including mountain ranges, would long ago have been worn down to near sea level, that is to the condition of *peneplain* (almost a

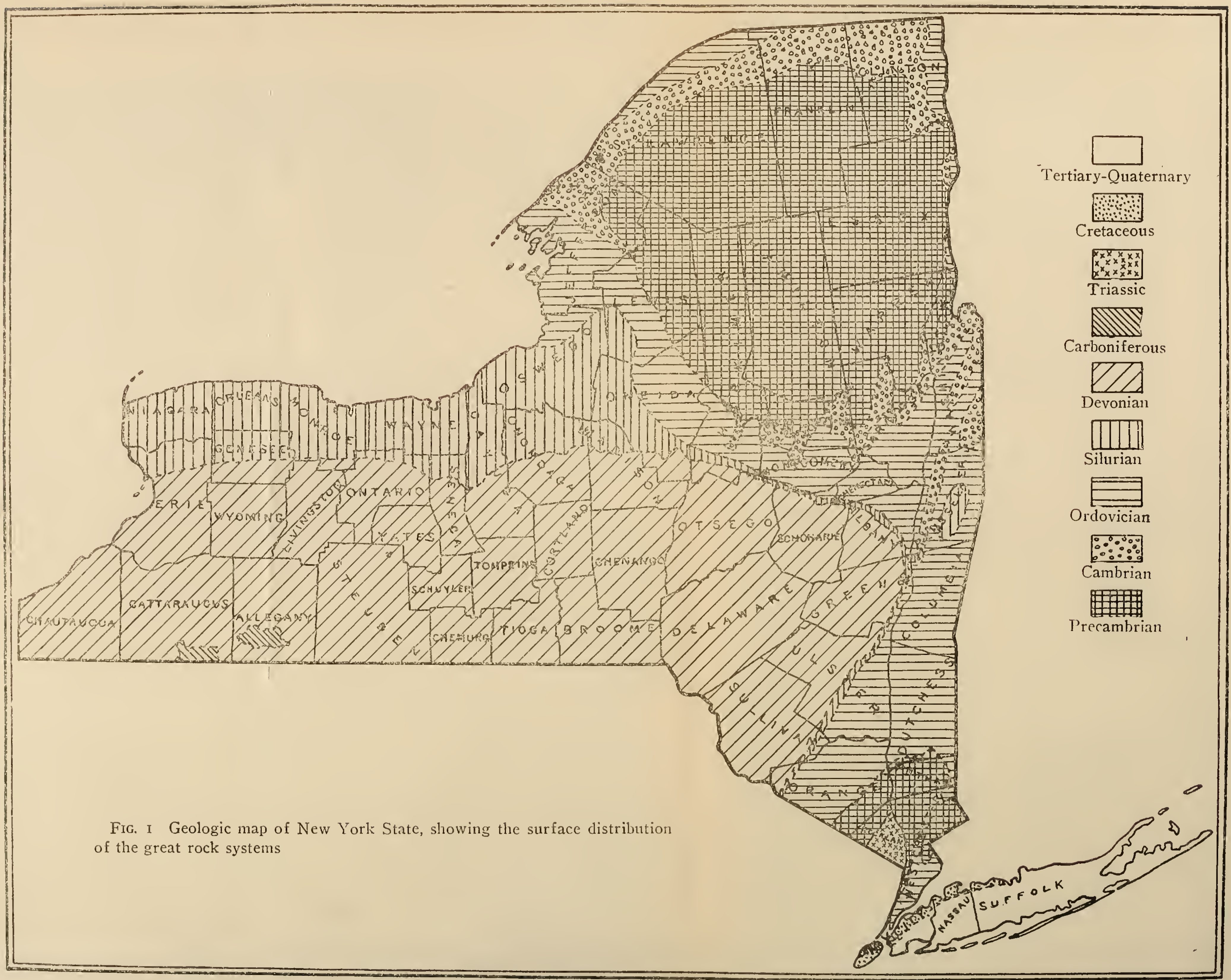


FIG. 1 Geologic map of New York State, showing the surface distribution of the great rock systems

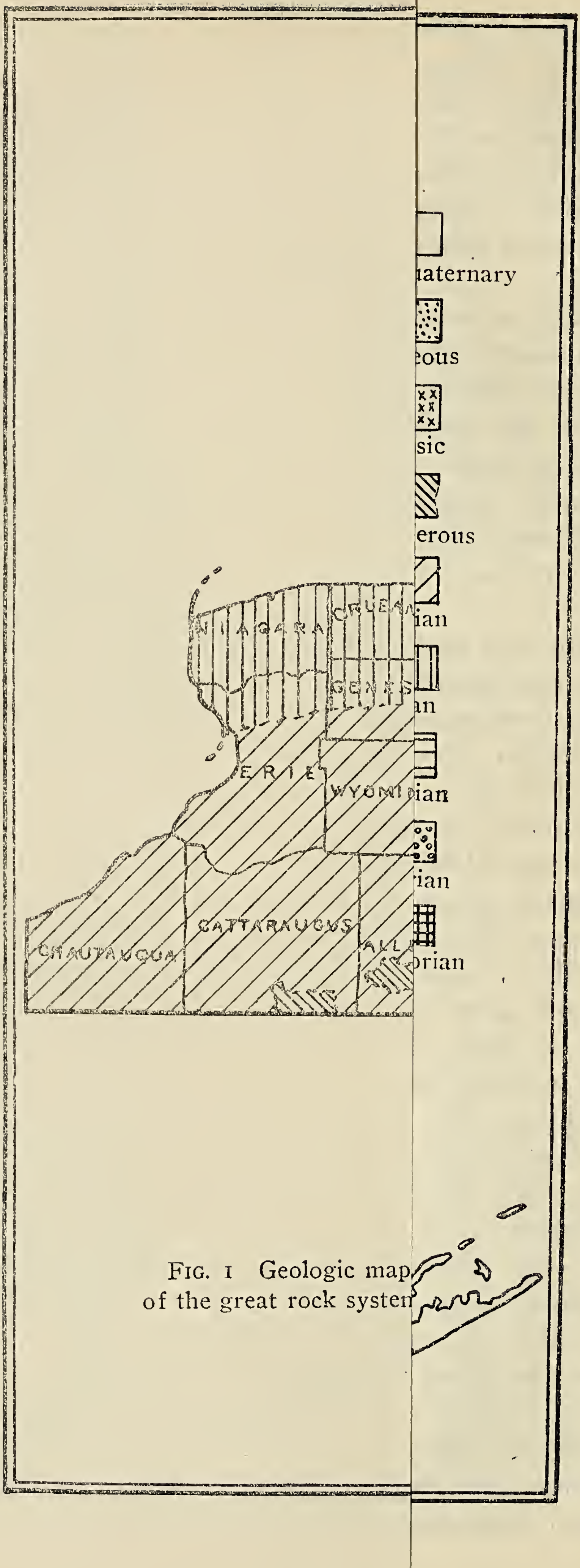


Fig. 1 Geologic map
of the great rock systen

plain). The former lofty Appalachians were thus worn down to the condition of a peneplain which has since been somewhat rejuvenated by elevation. Accordingly, that familiar expression "the everlasting hills" is much more exact when made to read "the everlastingly changing hills."

Still another important process by which the physical features of the earth have often been changed is through *vulcanism,* or igneous activity in general. By this means materials are brought up from within the earth to or near its surface. Thus an active volcano violently ejects rock fragments, dust etc., or more quietly pours out molten rock, while in many cases great masses of molten rocks have been forced upward into the crust of the earth without reaching the surface and hence have slowly cooled at greater or lesser depths below the surface. Such igneous rocks have become exposed to view only by subsequent erosion of the region.

In order to understand the physical history of the State it is necessary to know that significant changes, like those above described, have long been, and now are, taking place. In tracing this history we shall see how all these natural processes have operated to bring the State into its present condition. It is also necessary to understand that the known history of the earth has been carefully divided into great eras, and into lesser periods and epochs, and that these constitute what is called the geologic time scale. This time scale is important to the reader because the principal events in the history of the State will be taken up, so far as they are recorded, in regular order according to that scale. In the first table the names of eras and periods are mostly of world-wide usage, while the names of subdivisions (epochs) of the periods are much more local in usage and, in the second table, only those are given which apply to New York State.

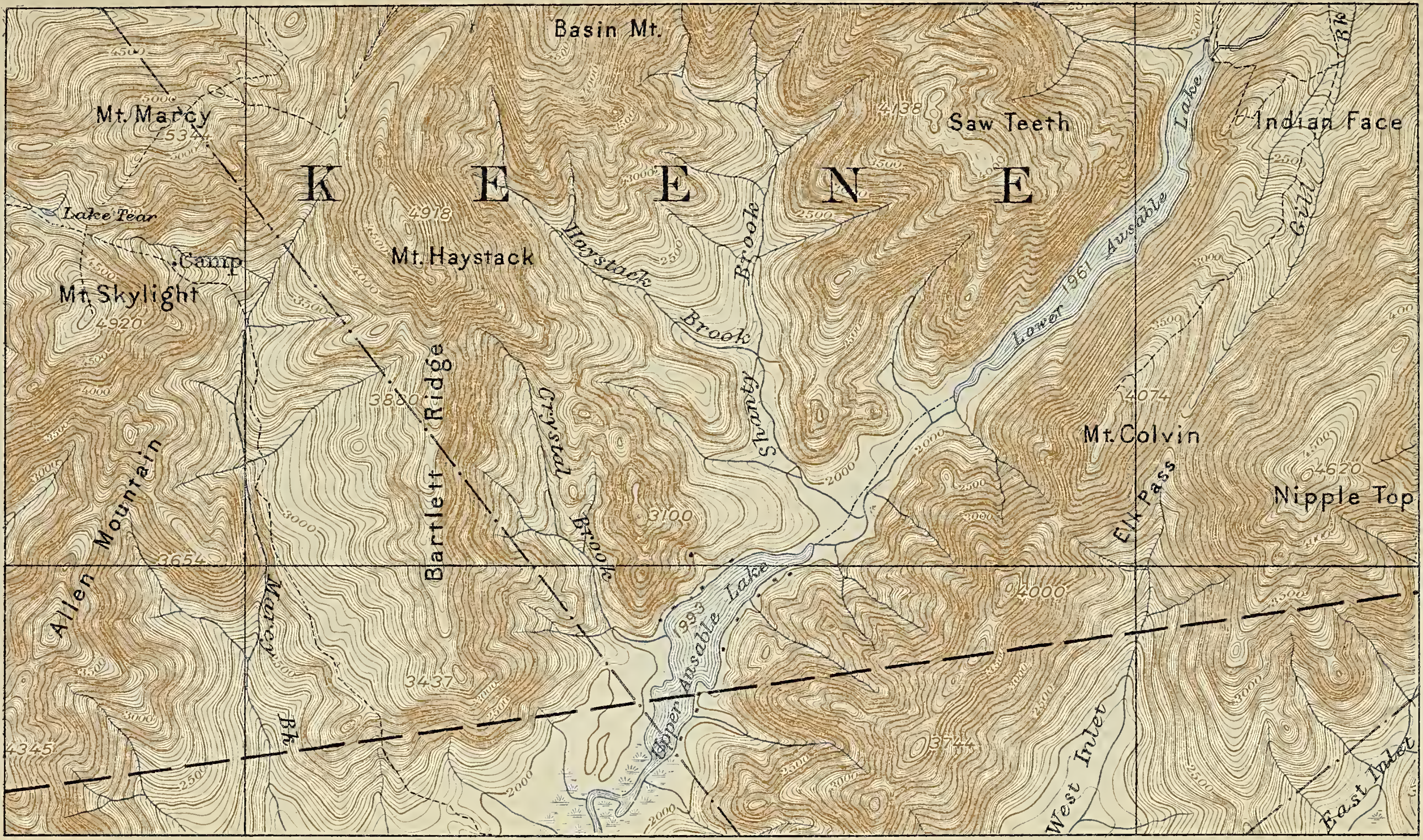
Geologic Time Scale

ERAS	PERIODS	DOMINANT LIFE
Cenozoic	Quaternary	Age of man
	Tertiary	Age of mammals
Mesozoic	Cretaceous	Age of reptiles, with birds first in the Jurassic, and trees and flowers of modern aspect first in the Cretaceous
	Jurassic	

	Triassic	Age of amphibians, with cycad plants common
Paleozoic	Permian	
	Carboniferous	Great coal age, with large nonflowering plants
	Devonian	Age of fishes
	Silurian	Age of invertebrates, with some very simple fishes in the Silurian
	Ordovician	
	Cambrian	
Proterozoic	Algonkian	Earliest known forms of life but records very imperfect
Archeozoic	Archean	

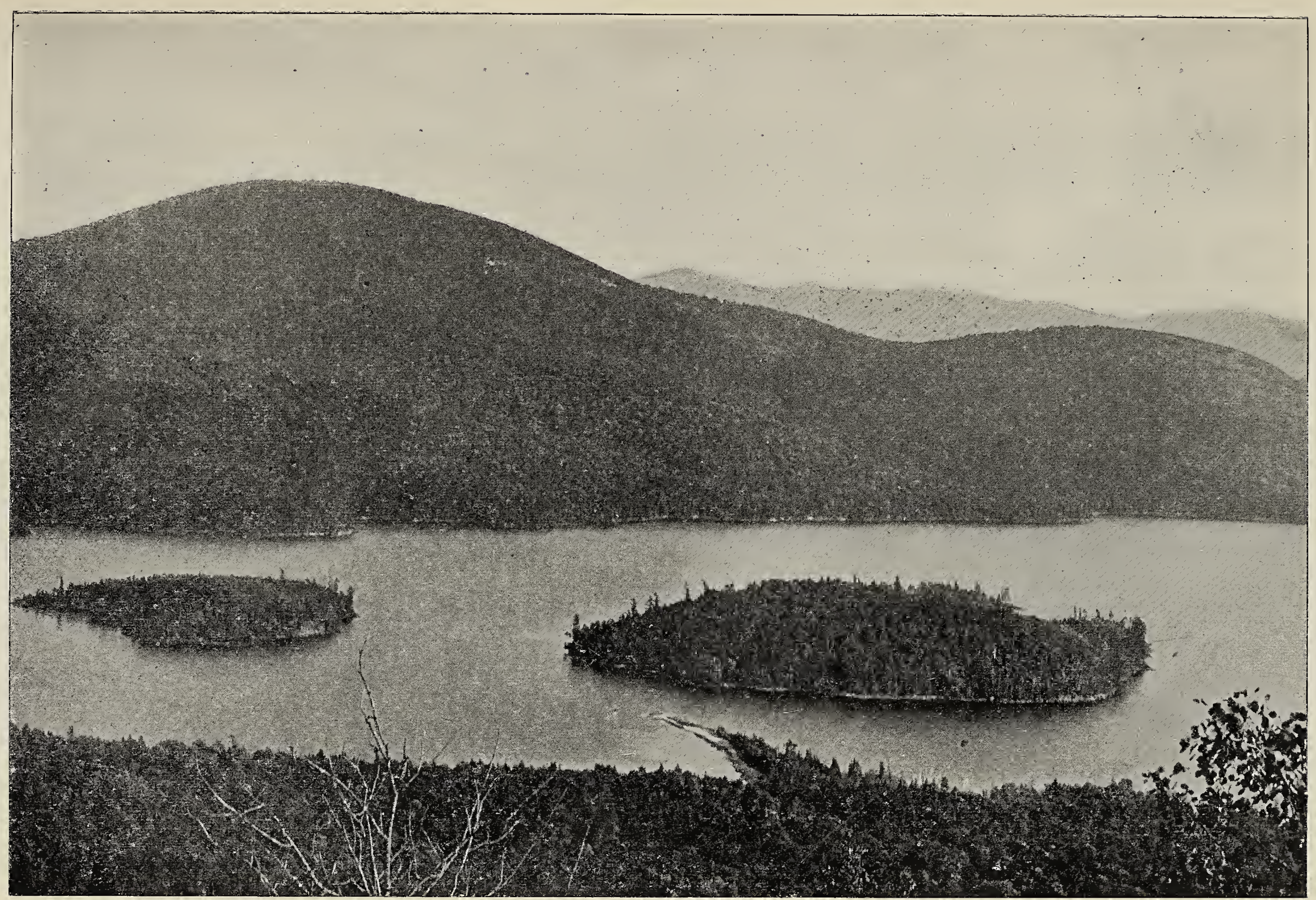
PERIODS, EPOCHS, AND ROCK FORMATIONS IN NEW YORK STATE

Quaternary	Recent clay beds, alluvium etc.	Surface deposits very common over the State
	Pleistocene. Glacial clay, sand, gravel, boulders etc.	
Tertiary	Pliocene	Sands, clays and gravels on Long Island
	Miocene	
Cretaceous	Monmouth	Clay and sand on Long and Staten Islands
	Matawan	
	Magothy	
	Raritan	
Jurassic	Absent (probably)	
Triassic	Newark sandstone and Palisade lava	Rockland county
Permian	Absent	
Carboniferous	Olean conglomerate	Allegany and Cattaraugus counties
	Cattaraugus shale	
Devonian	Catskill and Chemung sandstones	Catskills and southwestern New York
	Portage shale and sandstones	South-central and western New York
	Genesee shale	East-central to western New York
	Tully limestone	
	Hamilton shale	East-central to western New York and eastern base of Catskill mountains
	Marcellus shale	
	Onondaga limestone	
	Oriskany sandstone	
	Helderberg limestone	



The highest and most rugged Adirondack topography, as represented by a portion of the Mt. Marcy (U. S. G. S.) quadrangle. One of the northeast-southwest ridges, so common in the eastern Adirondacks, is shown just east of the lakes. The rocks are nearly all of plutonic igneous origin (anorthosite). Scale, about 1 mile to the inch. Those who are not familiar with the topographic map and its interpretation should refer to the explanation in the appendix.

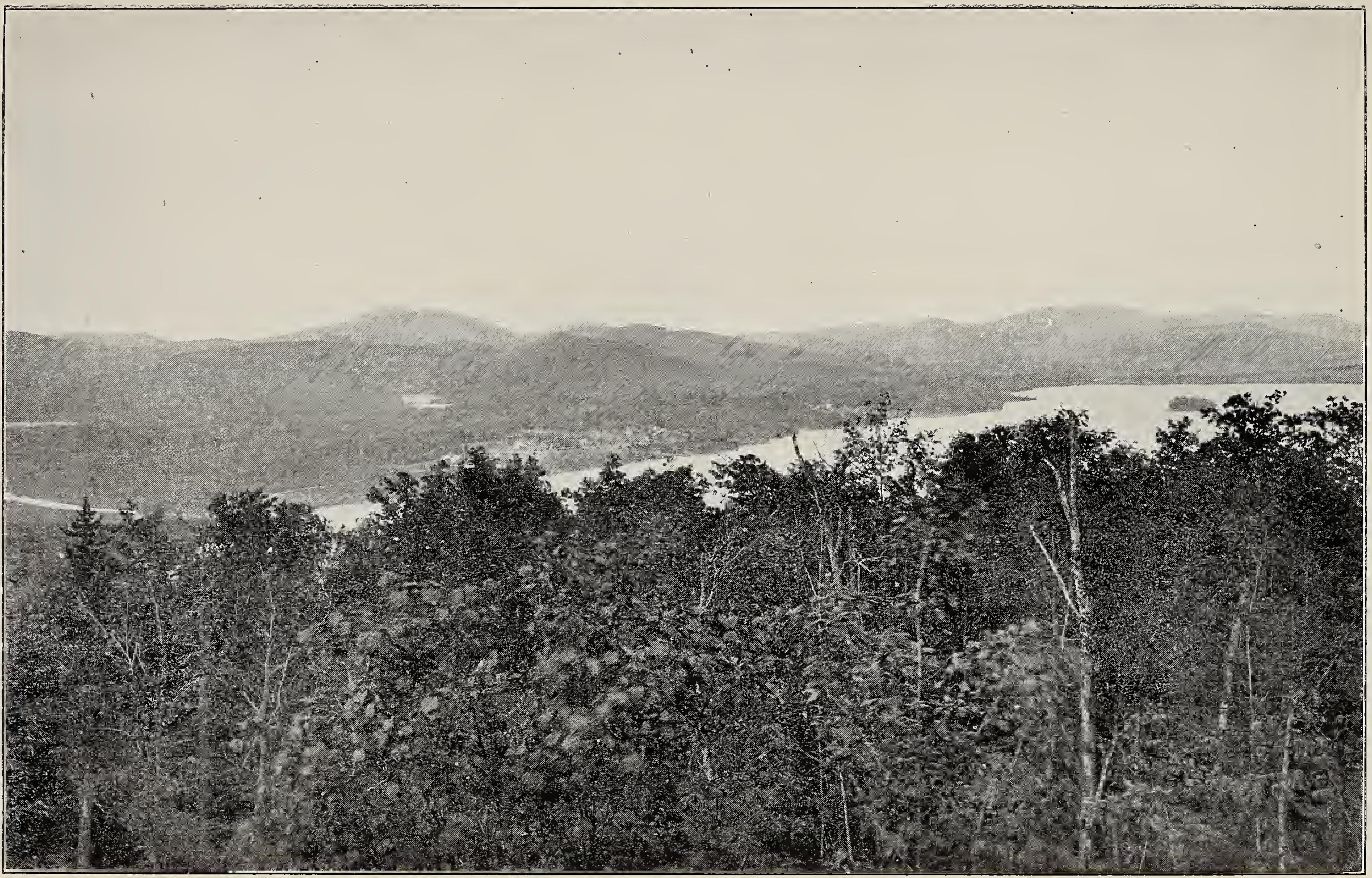
Plate 2



A typical view in the midst of the Adirondacks. Looking across Long lake from Buck mountain, showing Mt Kempshall and Blueberry mountain. Note the flowing outlines of the topography.

From N. Y. State Mus. Bul. 115, pl. 15

Plate 3



General view in the Adirondacks looking northward across Lake Pleasant (Hamilton county). Note the flowing outlines of the topography.

Photo loaned by John A. Cole, Lake Pleasant, N. Y.

Silurian	Manlius limestone Rondout waterlime Cobleskill limestone Salina shales, salt, waterlime, and Shawangunk conglomerate	Eastern to western New York except Shawangunk in eastern New York only
	Lockport and Guelph dolomites Rochester shale	Central to western New York
	Clinton shale, sandstone, limestone and iron ore	Central to western New York
	Medina and Oneida sandstone and conglomerate	Central to western New York
Ordovician	Frankfort shale and sandstone Utica shale	Central New York and western side of the Adirondacks
	Trenton limestone and shale Black river limestone Chazy limestone Beekmantown limestone	Around the Adirondacks and more or less in Hudson valley. Chazy absent from Mohawk valley
Cambrian	Little Falls dolomitic limestone Potsdam sandstone and limestone	Around the Adirondacks and some in southeastern New York
	Acadian limestone Georgian slate and quartzite	East of Hudson river from Washington county southward
Precambrian	Igneous series — Anorthosite, granite, syenite, gabbro and diabase Grenville metamorphosed sediments	Adirondacks and Hudson Highlands

Throughout this book the purpose is not merely to describe the physical features of the State, but also to constantly emphasize the history or evolution of those features. The idea which I would now convey to the reader has been admirably expressed by Professor Davis in his "The Physical Geography of Southern New England": "Geography still retains too much of its old-fashioned, irrational methods: it has not kept pace with the advance made by geology. In spite of what the geologist has learned about the evolution of geographical forms, the geographer still too generally treats them empirically, and thus loses acquaintance with one of the most interesting phases of his subject. . . . It is often maintained that a devoted study of the facts themselves, without regard to their meaning or development, will suffice to place them clearly enough before the mind; but this view is contradicted both by general experience in many subjects where rational explanation has replaced empirical generalization, and by the special experience of geography as well. Left to itself as an empirical study, in which the development of land forms was hardly allowed to enter, it has languished for many years, until it became a subject for continual complaint. . . . Today it is only by those who fail to see the direction of geographical progress, and who are ignorant of the progress already gained, that objection is made against the effort to bring every geographical fact under the explanation of natural processes. No one of active mind can look across our upland and fail to gather increased pleasure and profit from understanding its history. No one who looks upon geography as the study of the earth in relation to man can contemplate the contrast between glaciated New England [or New York] and nonglaciated Carolina without inquiring into the meaning of the contrast: he might as well study the Sahara and the Sudan without asking the reason for the dryness of the one and the moisture of the other."

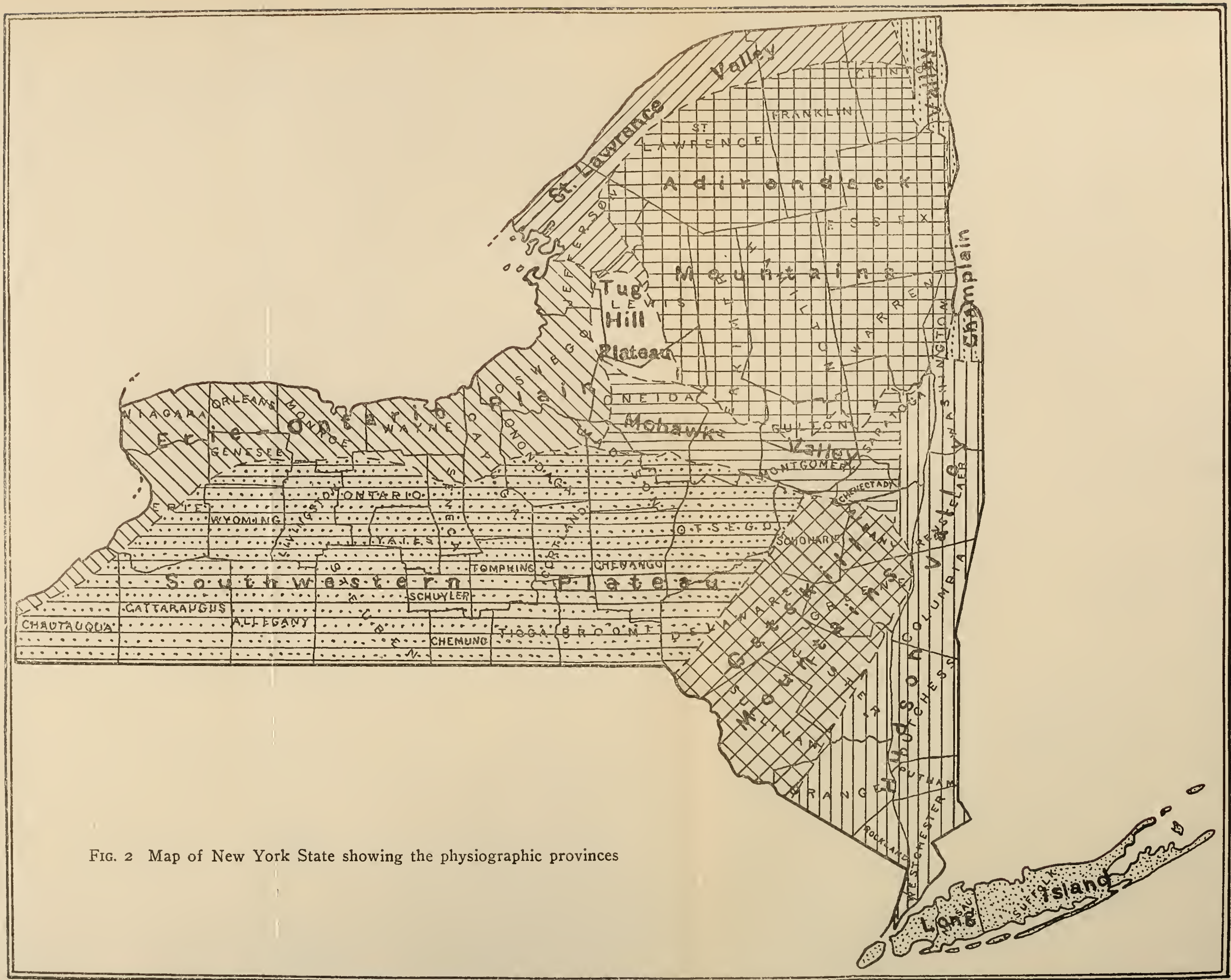


FIG. 2 Map of New York State showing the physiographic provinces

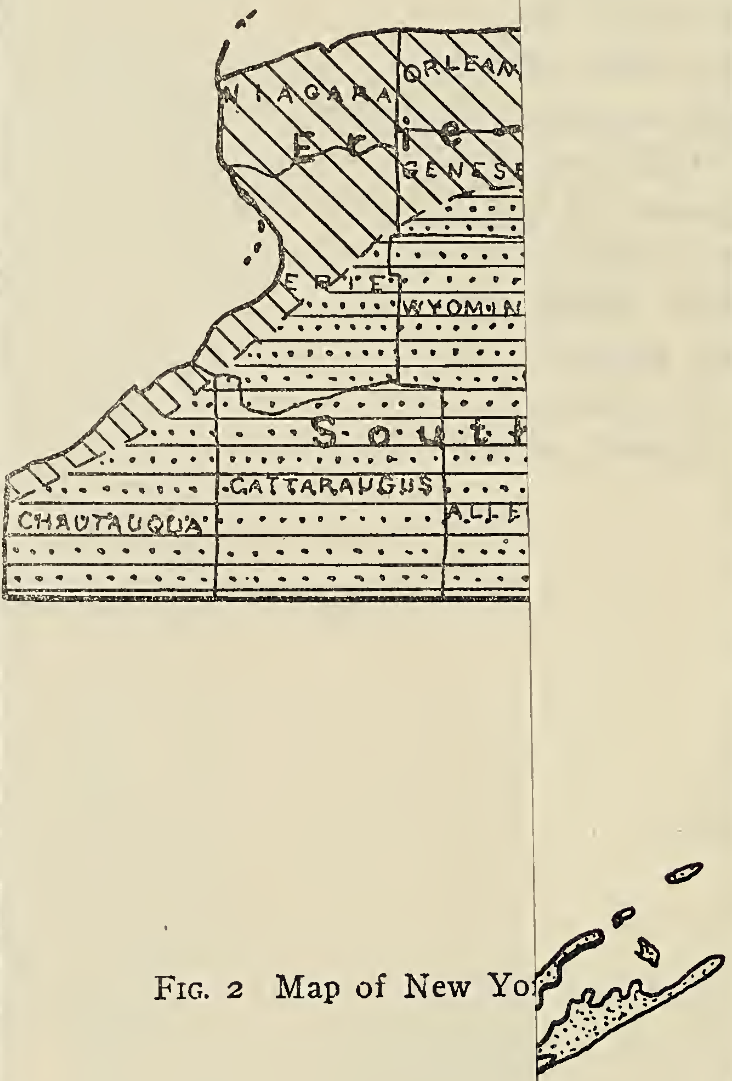


FIG. 2 Map of New Yo

Chapter 2

PHYSIOGRAPHIC PROVINCES, STRUCTURE AND DRAINAGE

GENERAL STATEMENT

The area of New York State is 49,170 square miles, including 1550 square miles of water. The range in altitude is from sea level to over 5000 feet, while the average elevation is about 900 feet. Mt Marcy (altitude 5344 feet) in Essex county is the highest mountain in the State.

For the sake of convenience in discussing the general physiography and structure, the writer has divided the State into certain well-defined physiographic provinces as shown on the accompanying map. Lest the sharp boundary lines convey a wrong impression, it should be stated that the provinces are, in reality, seldom sharply separated from each other (see figure 2).

ADIRONDACK MOUNTAIN PROVINCE

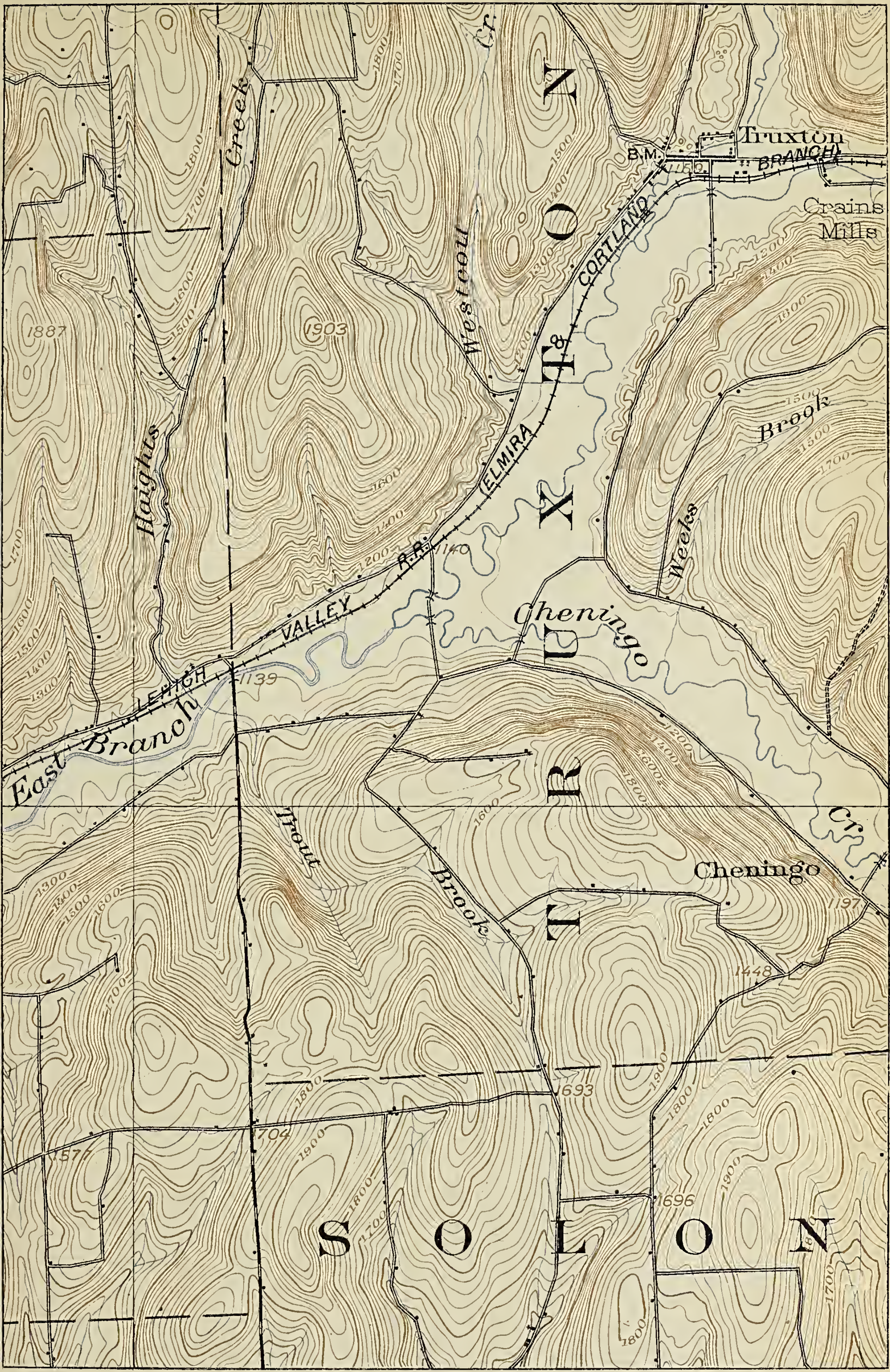
The Adirondack mountain province comprises fully one-fourth the area of the State, and it consists of a great, nearly circular mass of metamorphic and igneous rocks of very great age, that is, Prepaleozoic. This large mass of crystalline rocks is completely surrounded by the practically unaltered Cambrian and Ordovician rocks. The whole province is typically mountainous and heavily wooded, often being truly wilderness in character with very few roads or settlements other than summer resorts. Except along the immediate borders, the elevations range from 1000 to over 5000 feet. The greatest axis of elevation extends from southern Hamilton county (2000 feet) northeasterly well into Essex county where the highest mountains are grouped around Mt Marcy, and where the mountains commonly attain altitudes of from 3000 to 5000 feet (see plate 1). In the eastern and southeastern portions there is a well-defined tendency in the mountain masses to be arranged in long, nearly parallel ridges or "ranges" whose general trend is north-northeast south-southwest. This structural feature is due to numerous faults or fractures in the earth's crust and will be explained on a later page. In the northern and western portions the mountains are very irregularly arranged. Viewed as a whole there are no high, sharp-topped peaks which stand out prominently above the general mountain level, and the flowing or rounded outline of topography is by far the most common (see plates 2 and 3). The very ancient Grenville rocks occur throughout the region, and great masses of igneous rocks have been forced through these. All these rocks have been subjected to tremendous earth pressure which has folded and thoroughly metamorphosed them.

SOUTHWESTERN PLATEAU PROVINCE

This, the largest clearly defined physiographic province, occupies nearly one-third of the area of the State. The rocks are all unaltered sediments of Devonian age, except a few small patches of Carboniferous rocks in the southwest, and consist of shales, sandstones, and conglomerates. These formations exist as vast sheets or layers piled one upon another, with an aggregate thickness of several thousand feet (see figures 3 and 5). In marked contrast to the Adirondack province, the rock masses of this southwestern plateau are practically devoid of displacements, the only disturbance being a slight tilt (30 to 50 feet a mile) of all the strata to the south or southwest, associated with low northeast-southwest undulation.

Although this plateau is considerably trenched or dissected by streams, it is nevertheless not a mountainous country, there being no high ranges or peaks standing out prominently. The elevation of the province varies from 500 to 600 feet on the northern side to over 2000 feet on the eastern and western sides. A notable feature is the distinct sagging of the plateau toward the middle portion. This sagged or depressed portion is occupied by the Finger Lakes, especially that portion filled by the south ends of Cayuga and Seneca lakes and the valleys which enter them from the south in the region of Chemung and Tioga counties. It is possible, by traveling along Seneca lake and thence southward to Elmira and the Chemung river, to pass entirely across the plateau province from north to south without attaining an altitude of much over 900 feet, which is on the divide between Watkins and Elmira.

Physiographically, the Plateau province is really but the northernmost extension of the great plateau which lies along the western base of the Appalachian mountains. On the east the province is bounded by the Catskill mountains which are in no sense sharply separated from the plateau itself. On the west and north the province is bounded by the Erie-Ontario plain and Mohawk valley provinces. The northern limit is rather clearly marked by what is known as the "Helderberg escarpment" of Devonian limestone. This limestone, being of considerable thickness and more resistant



Typical southwestern plateau topography. Note the numerous irregular shaped hills, the high general level of the country and the deep broad-bottomed valleys occupied by the larger streams. The rocks are shales and sandstones of Devonian age. From Cortland (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

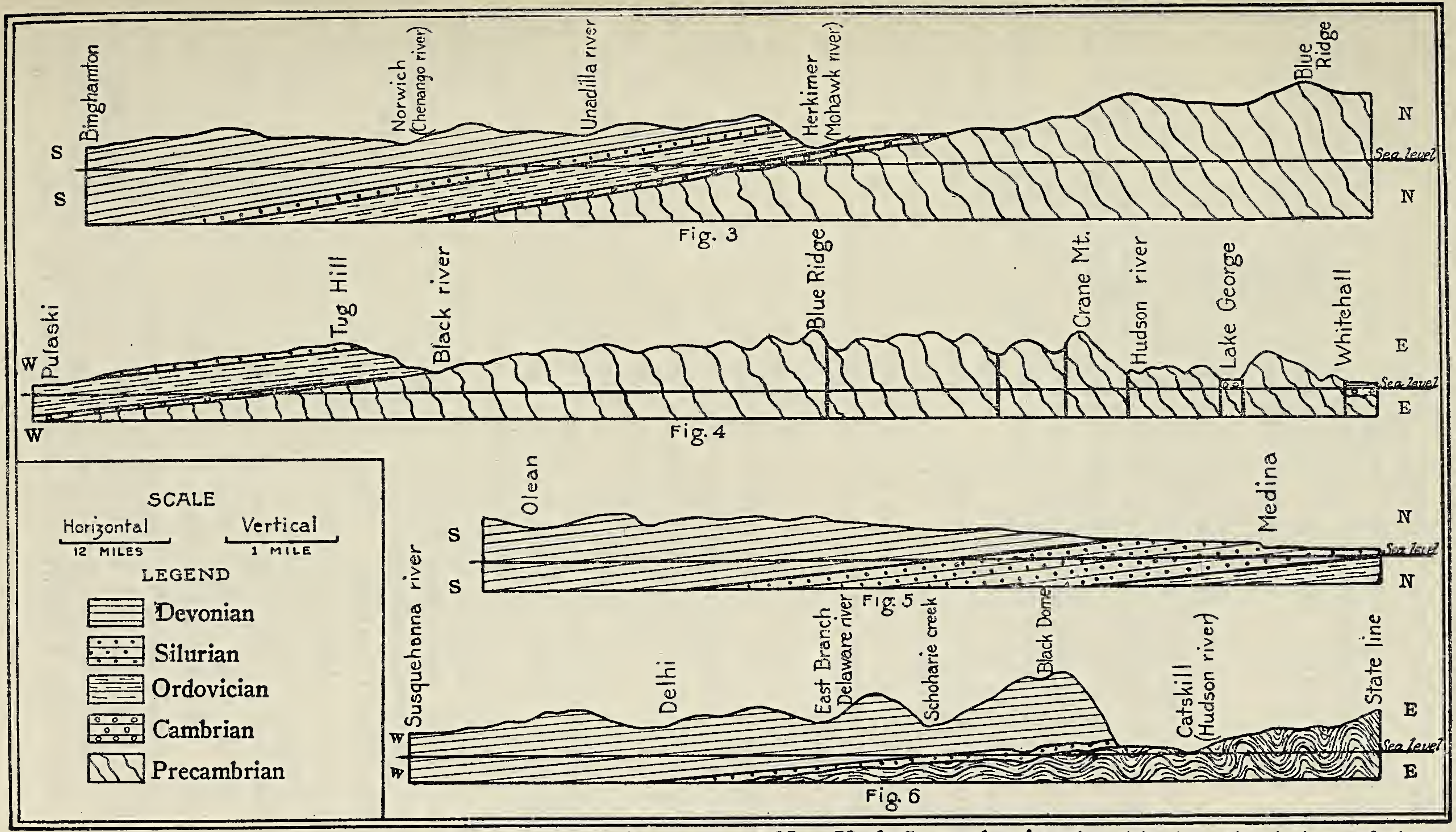


FIG. 3–6 Generalized structure sections through various parts of New York State, showing the altitude and relations of the great rock masses.

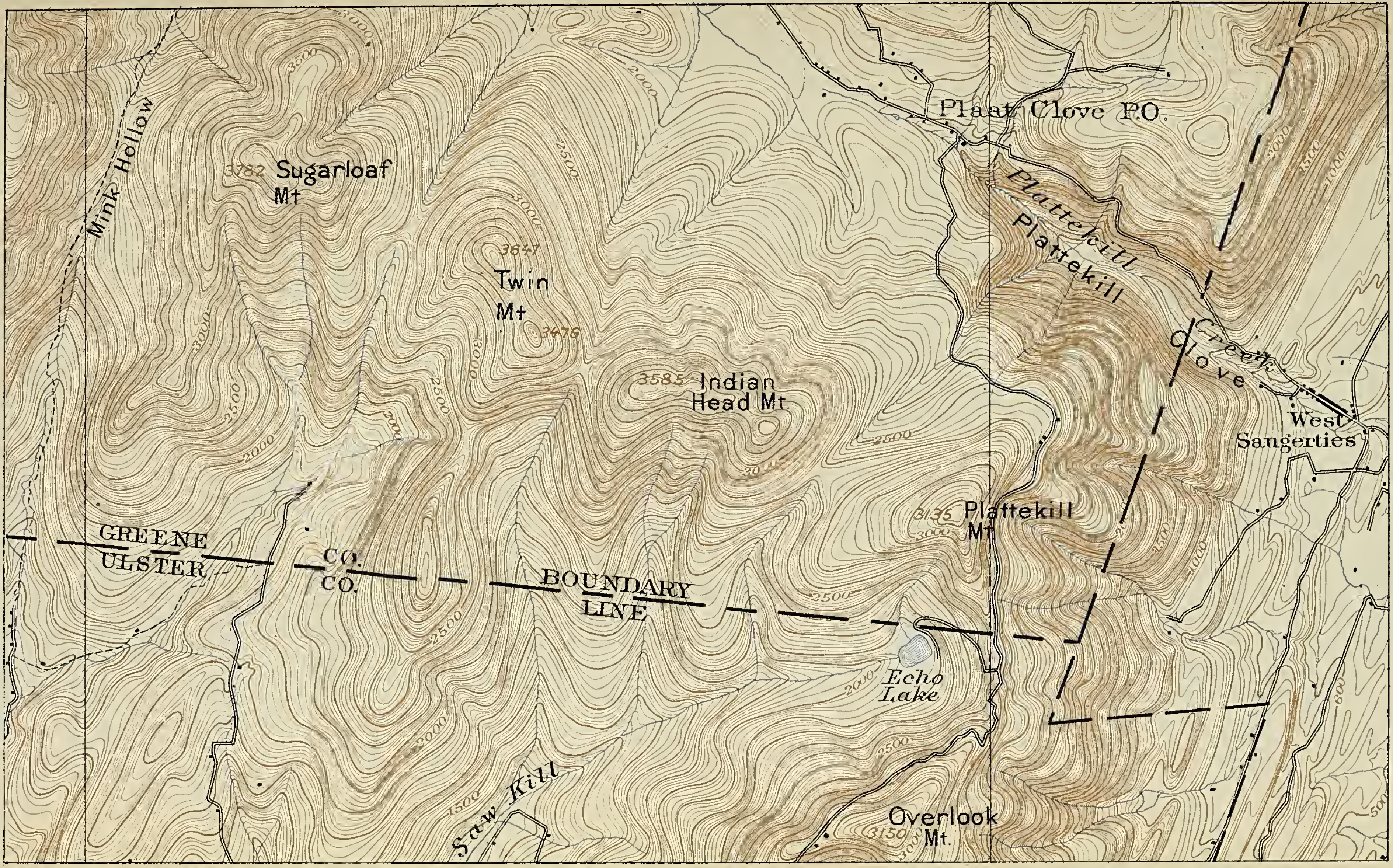
than the neighboring formations, has generally stood out boldly against erosion, thus causing an abrupt change in relief. The escarpment is particularly prominent along the boundary of the plateau and Mohawk valley provinces where the hard limestone lies at an altitude of more than 1000 feet, and directly overlies the soft shales of the valley whose altitude is only a few hundred feet.

CATSKILL MOUNTAIN PROVINCE

This is the most rugged of all provinces in the State and, next to the Adirondacks, contains the greatest elevations. Slide mountain (4205 feet) is the highest, while a number of points range from 3500 to over 4000 feet in altitude.

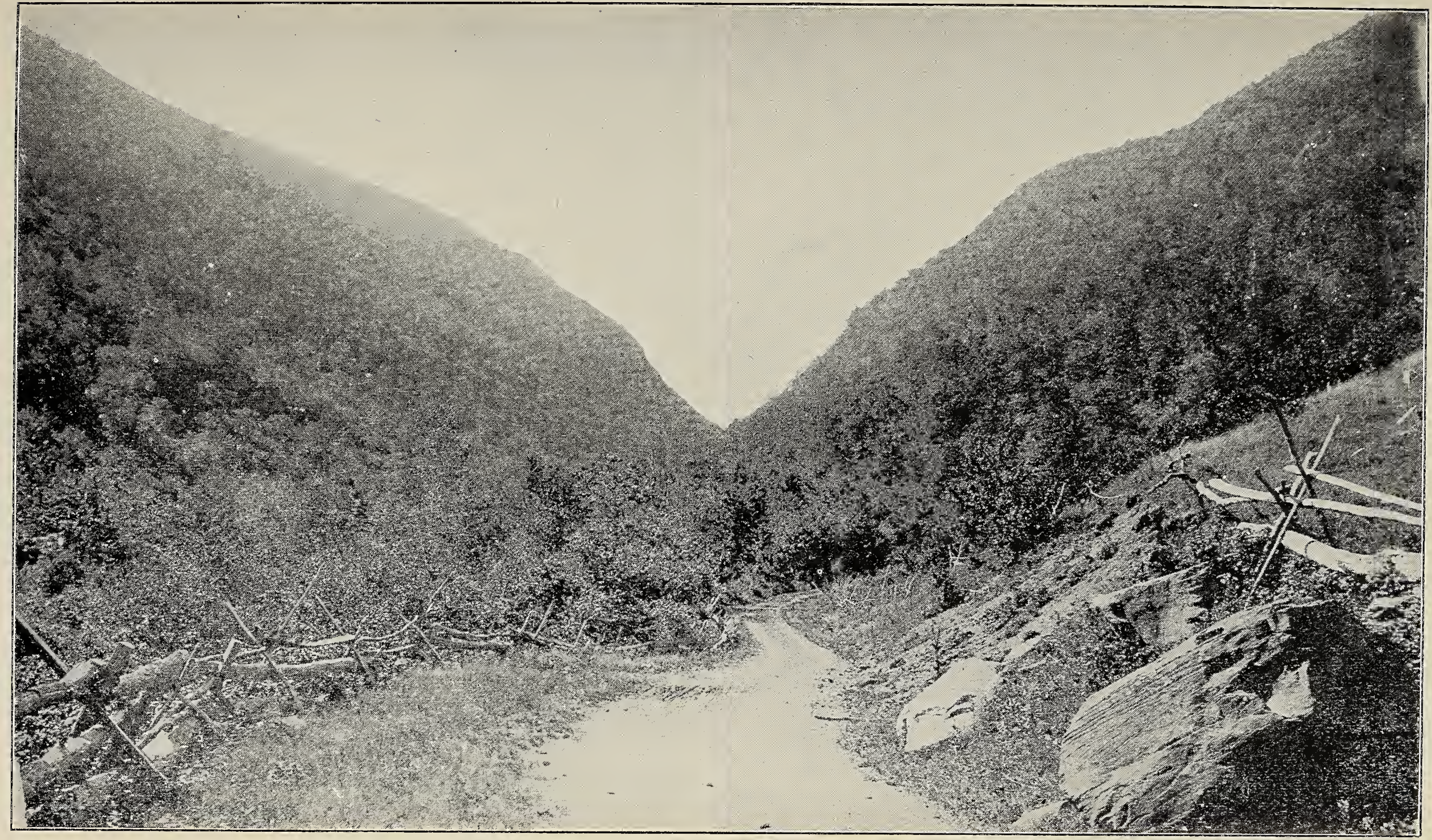
The rocks are all of Devonian age and they consist almost entirely of sandstones and conglomerates. Except for a slight westward undulation, these rocks are arranged in practically horizontal layers and show an aggregate thickness of several thousand feet (see figure 6). Lying under these Devonian rocks, and outcropping at the very base of the mountains on the north and east, are various formations of Silurian age.

The term "mountains" as applied to the Catskills requires some explanation. The more typical mountains of the world have been formed by folding or faulting of the strata, or by igneous activity, or by two or all of these causes combined. For example, in the development of the Appalachians both folding and faulting have played prominent parts, but in mountains like the Sierras or Adirondacks, folding, faulting, and igneous action have all been important. The Catskills, however, in which these typical mountain phenomena are wholly lacking, are to be properly placed in the category of what we may call "erosion mountains." Mountains of the pure erosion type are due to an uplift of land high above sea level, followed by deep dissection of the elevated mass by the action of streams. The Catskills are only an easterly extension of the plateau province where the rocks are more resistant and perhaps the elevation of the region was greater, so that the streams were able to cut deeper trenches while the harder rocks of the divides have so far prevented a general wearing down of the region. The Catskills furnish a remarkable example of a high plateau deeply dissected by numerous streams. The whole topography is very rugged, all being much like that of the highest portion of the Adirondacks around Mount Marcy (compare plates 2 and 5). The Catskills, however, lacking the proper structural



Map of part of the Catskill province showing the high, rugged character of the mountains and the remarkably steep, high eastern front of the province overlooking the great Hudson valley. From the Kaaterskill (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

Plate 6



The pass between Hunter and Plateau mountains in the Catskills. This is a fine example of the deep, steep-sided, V-shaped valleys so characteristic of this province.

From Annual Rep't N. Y. State Geol., 1897, pl. 20, facing p. 282

features, show practically no tendency to parallel arrangement of ridges or mountains as is so common in the Adirondacks.

On the south the Catskill province almost grades into the folded region of the Appalachians, while on the west it gradually merges into the southwestern plateau. On the north the Helderberg escarpment, standing out abruptly and to a great height, forms a sharp boundary. On the eastern side the Catskills present a very steep, high front facing the Hudson valley. This steep front rises about 3000 feet and consists of hard Devonian sandstones and conglomerates overlying the Silurian strata (see figure 6).

MOHAWK VALLEY PROVINCE

The Mohawk valley province, though comparatively small, is of great importance because it so clearly separates the Adirondack highlands on the north from the highlands of the Catskills and southwestern plateau provinces on the south. In fact it should be noted that the Mohawk valley is by far the lowest passageway across the mountains between the St Lawrence river and the southern end of the Appalachian range. This low pass is one of the great eastern "gateways" which, with the St Lawrence, have afforded the easiest means of communication between the Atlantic seaboard and the region west of the Appalachian mountains.

The comparatively narrow inner valley through which the river now flows is often erroneously called the Mohawk valley, but in reality the whole depression, from 10 to 30 miles wide and fully 1000 feet deep, between the northern and southern highlands of the State, should be called the Mohawk valley. At Little Falls the inner valley narrows to a gorge several hundred feet deep, where the river has cut its way through a preglacial divide (see plate 7 and figure 7). Had it not been for the recent cutting of this gorge (see explanation accompanying plate 44 in chapter 6) through the barrier at Little Falls, the Mohawk valley would never have been so important as a great gateway between the Atlantic coast and the west. Today the four tracks of the New York Central Railroad, two tracks of the West Shore Railroad, the Barge canal, an important highway, many telegraph and telephone wires, and the Mohawk river all pass through this narrow gorge within a few hundred feet of sea level. Eastward and westward from Little Falls, the inner valley is generally rather wide and open (see plate 7). At Little Falls the Mohawk river is less than 400 feet above sea level and even at Rome, in the western part of the province, the river shows an altitude of only 420 feet.

The principal rocks of the province are shales, sandstones and limestones of Cambrian and Ordovician ages; of these the soft, black shales of Trenton, Utica, and Frankfort ages are in greatest abundance. The valley owes its existence largely to the presence of

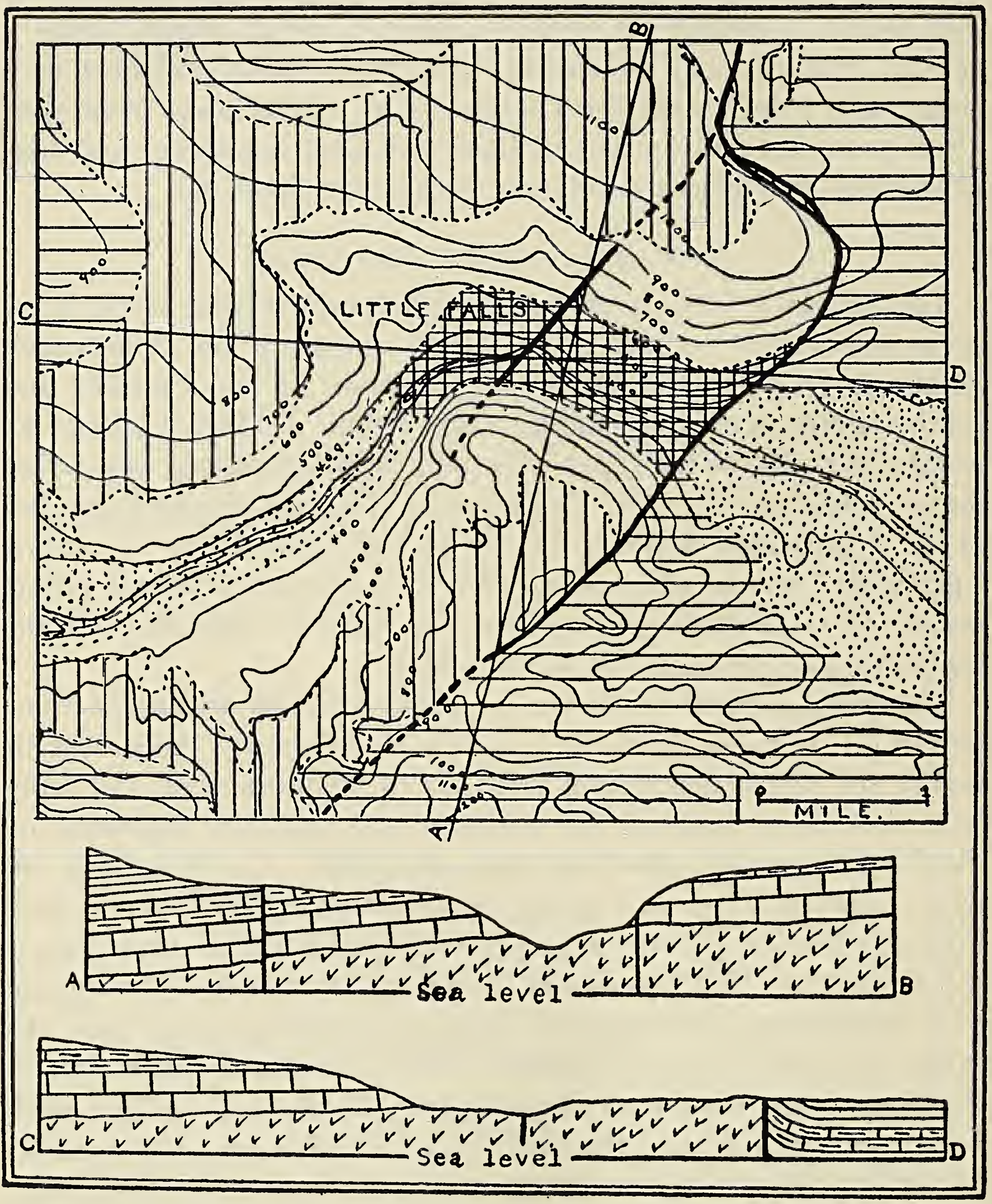
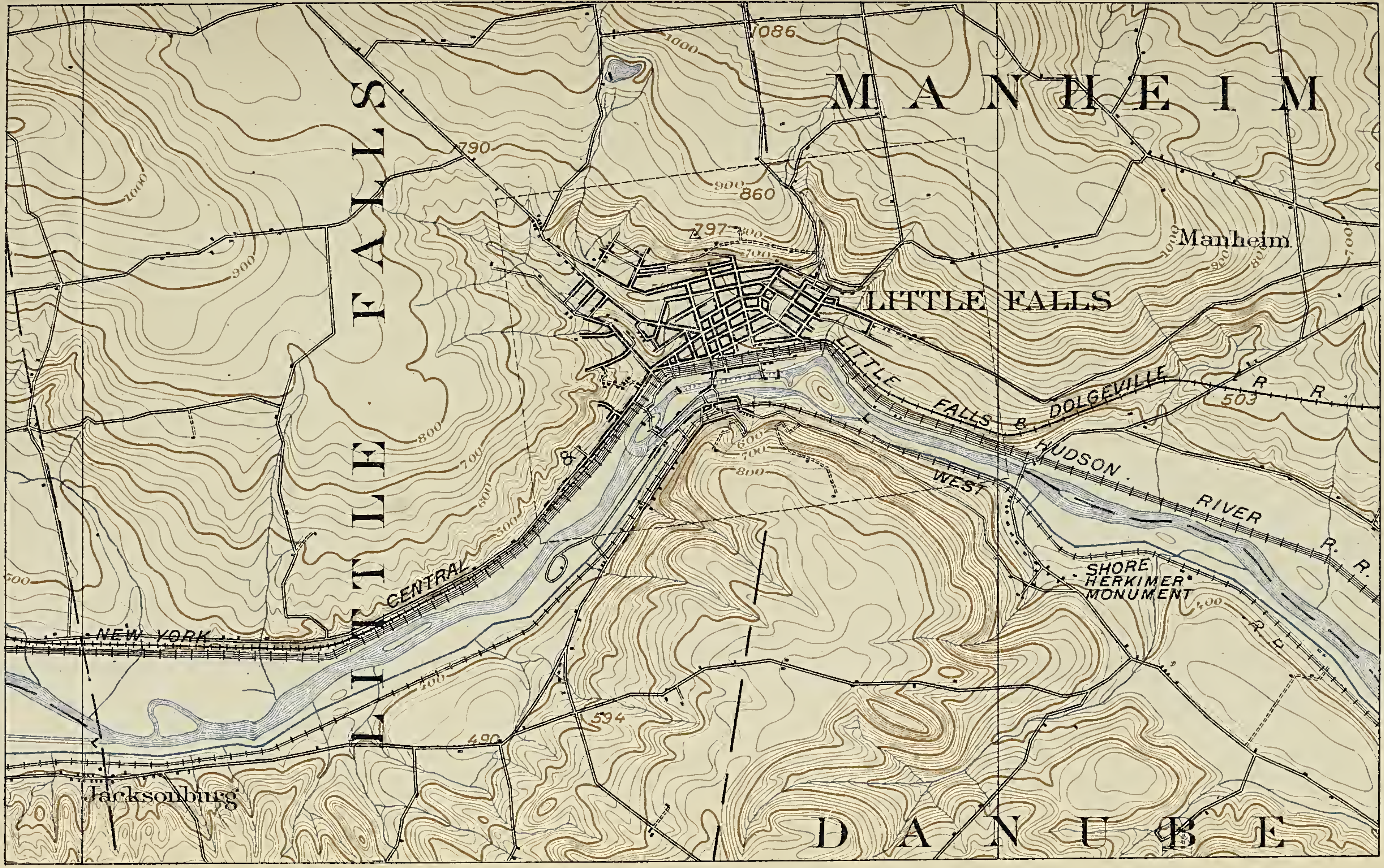


Fig. 7 Geologic and topographic sketch map and structure sections of the vicinity of Little Falls. Crosslined area at bottom of gorge=Precambrian rock (syenite); blank areas=Little Falls (Cambrian) dolomite; vertical line areas=Trenton (Ordovician) limestone and shale; horizontal lined areas=Utica (Ordovician) shale; dotted areas=Quaternary sand and gravel. Heavy black lines are faults. The structure sections show the condition of things along the lines AB and CD. In the sections the vertical scale is four times exaggerated.

Based upon map by H. P. Cushing.



Topographic map showing the deep, narrow gorge of the Mohawk river at Little Falls. The walls of the gorge rise fully 500 feet above the river which is less than 400 feet above sea level. The gorge is postglacial in origin and before the great ice age it was replaced by an important divide with one stream (Mohawk river) flowing eastward and another stream (Rome river) flowing westward. Part of Little Falls (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

this belt of soft shales lying between the hard crystalline rocks of the Adirondacks on the north and the comparatively hard limestones immediately southward. The work of erosion has made rapid progress in this belt of weak rocks, and at two places, Little Falls and "The Noses" (Yosts), the river has cut down to the Precambrian (Adirondack) rock. In general, the rock formations of the province tilt slightly southwestward and show folding only on a very small scale. From Little Falls eastward, however, the strata are greatly disturbed by numerous nearly north-south faults which are often of considerable magnitude (see figure 25).

ERIE-ONTARIO PLAINS PROVINCE

On the extreme western side of the State, and lying between Lake Erie and the Southwestern plateau, there is a strip of land only a few miles wide which may be called the Erie plain. This plain is of very low relief and slopes from an altitude of from 800 to 900 feet down to the level of Lake Erie, whose altitude is 573 feet. Where the Erie plain joins the Southwestern plateau there is a very decided change of slope. The rocks underlying this plain are dark shales of Devonian age and show the usual slight southwestward tilt (see plate 31).

The Ontario plain is much larger, and it lies between Lake Ontario and the southwestern plateau, the southerly boundary being marked by the "Helderberg escarpment." This large province slopes gradually to the shores of Lake Ontario, and it is remarkably free from relief features of any considerable magnitude. A feature that deserves mention is the presence of many hundreds of low, glacial knobs (drumlins) which are thickly scattered over the whole plain between Rochester and Syracuse (see plate 42). Another feature which serves to break the monotony of the plain on the west is the low but distinct escarpment of Niagara limestone, which extends from Lewiston eastward to beyond Lockport. On the east the Ontario plain gradually merges into the Mohawk valley province on the one hand, and on the other hand comes against the western foot of the highlands of the Tug Hill province.

The rocks underlying the Ontario plain are chiefly sandstones, limestones and shales of Silurian age, which show the usual tilt toward the south. At the extreme northeast, limestone and shale of Ordovician age are present and these show a slight westward tilt.

TUG HILL PROVINCE

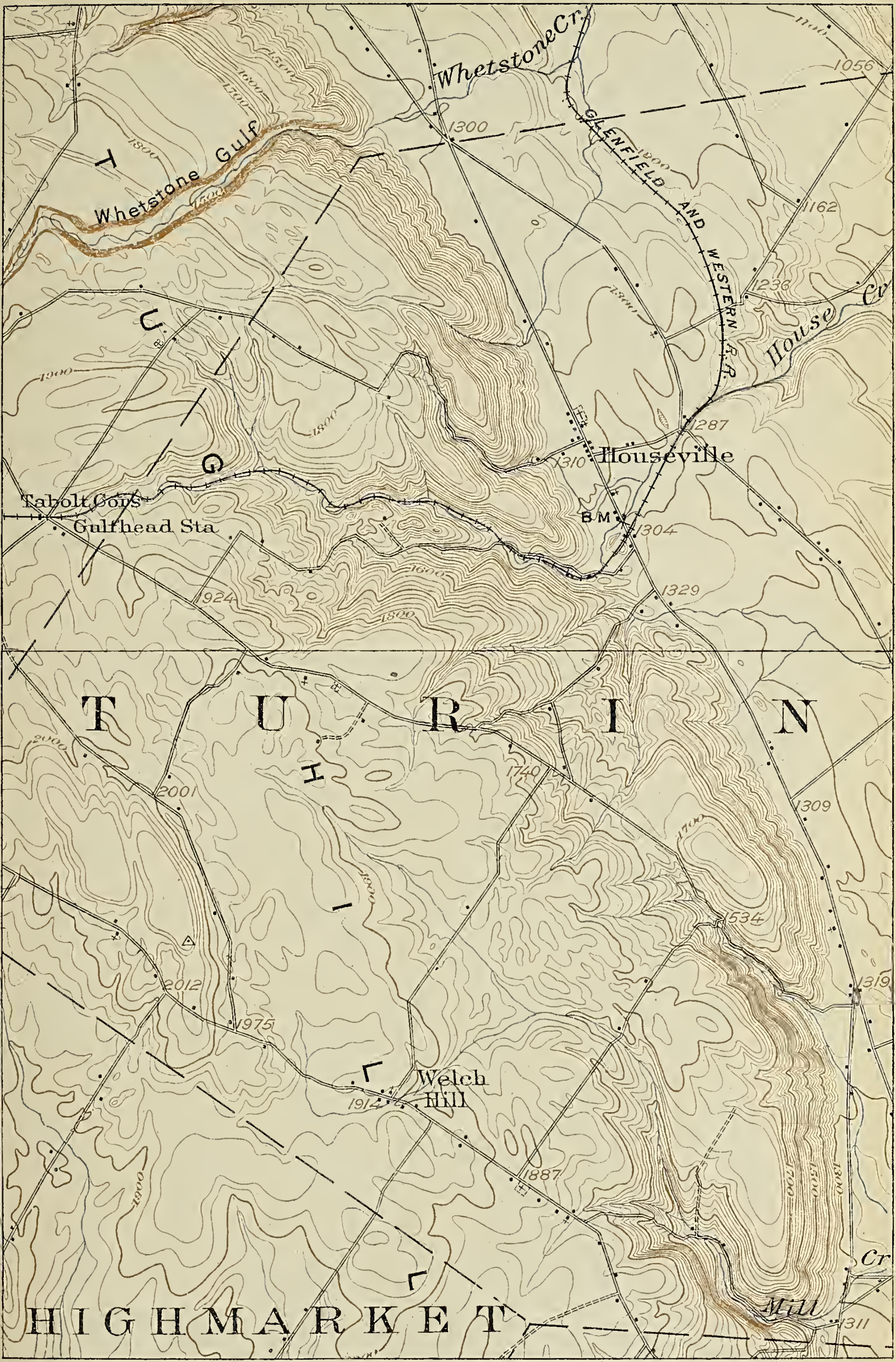
The Tug Hill region is worthy of recognition as a distinct physiographic province because we have here a highland mass of considerable extent entirely separated from the neighboring provinces. The highest point, six miles west-northwest of Lyons Falls, Lewis county, reaches an altitude of nearly 2100 feet, while the central portion of the province, covering many square miles, is remarkably flat and swampy with the general level above 1800 feet of elevation. On a smaller scale, this is as truly a plateau as the great Southwestern plateau already described. It is interesting to note that this Tug Hill plateau is merely an erosion remnant of the great upraised Cretaceous peneplain (see chapter 5) which formerly included all of New York State.

On the south and west this province slopes rapidly downward to the lowlands of the Mohawk valley and Ontario plain provinces, while on the east and north the Black river valley sharply separates this province from the Adirondack and St Lawrence valley provinces. The rapid descent into the Black river valley bottom is everywhere 1000 feet or more over a series of high, steep terrace fronts (see plate 8). In passing, it should be stated that, though seldom recognized, this Black river depression takes rank as one of the few greatest valleys within the borders of the State.

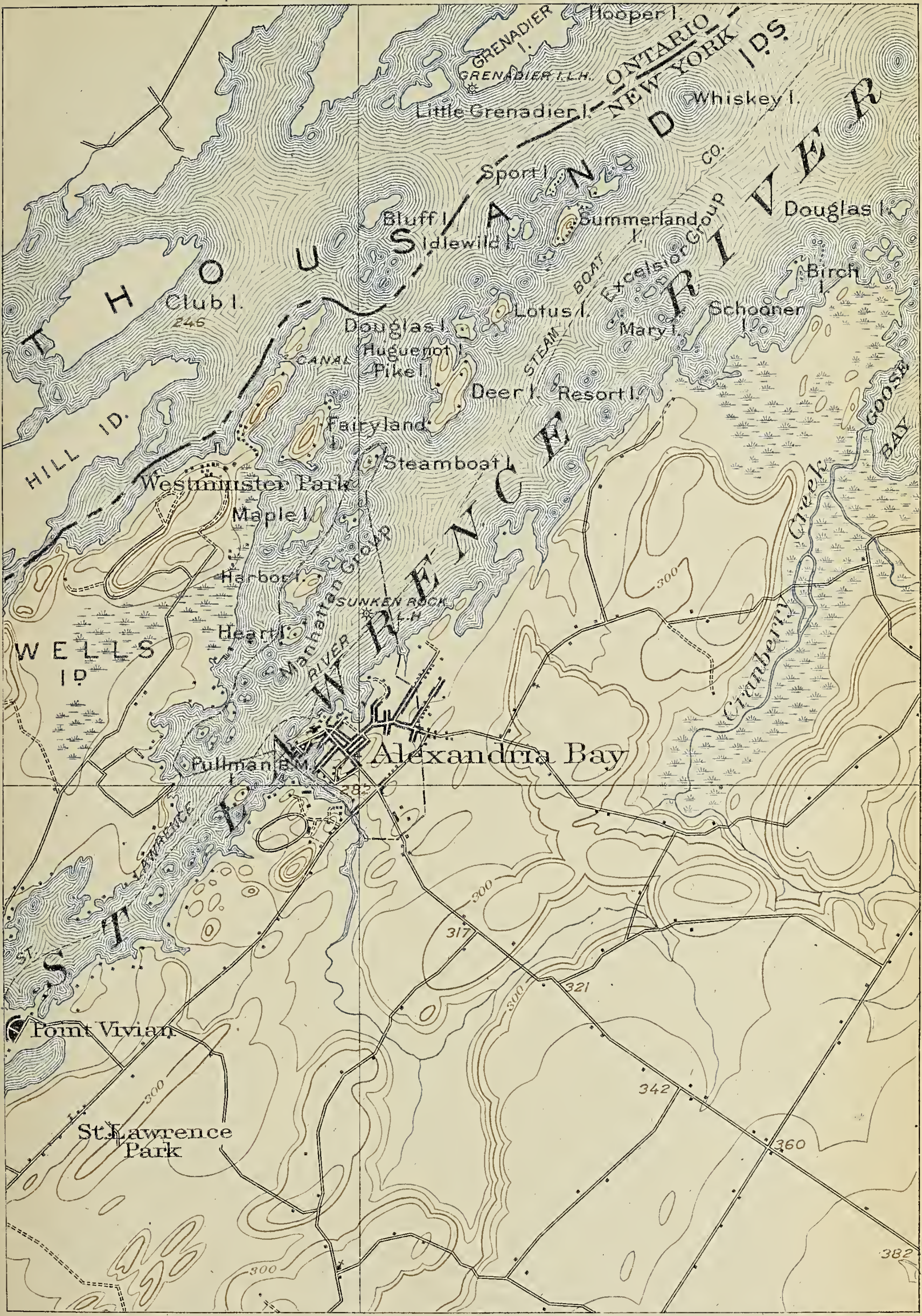
Near Boonville, and at an elevation of about 1100 feet, occurs the division of drainage between the Mohawk and Black rivers, and this divide forms the highest land connecting the Tug Hill and Adirondack provinces. But in spite of this partial connection and the close proximity of the province to the Adirondacks, the rock formations and structure are wholly different from those of the Adirondacks while they greatly resemble those of the Southwestern plateau. The rocks are all of lower Paleozoic (chiefly Ordovician) age, with several hundred feet of limestone at the base followed by about a thousand feet of shales, the whole being capped by a resistant sandstone of Silurian age. These strata tilt slightly westward but they have never been disturbed by folding, faulting, or igneous activity (see figure 35).

ST LAWRENCE VALLEY PROVINCE

The St Lawrence valley, lying along the northern boundary of the State, is a great, open depression of comparatively simple structure lying near sea level. Where the river leaves Lake Ontario, the elevation is only 247 feet, while points with elevations more than



A portion of the Port Leyden (U. S. G. S.) quadrangle, illustrating the topography of the Tug hill plateau. Note the high, general plateau level at from 1800 to 2000 feet above sea level and the abrupt termination of this plateau on the east side. Whetstone gulf is a fine example of numerous gorges cut through the steep plateau front. Scale, about 1 mile to the inch.



The Thousand Islands region in the vicinity of Alexandria Bay. The broad river, dotted with islands, does not here occupy a distinct stream channel in the usual sense of the term. A removal of the water would show that the topography of the river bottom is in no way essentially different from that of the country just south of Alexandria Bay. From Alexandria Bay (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

a few hundred feet seldom occur within the province. As shown on the accompanying map (plate 9,) low hills are common over the valley floor. The Thousand Islands form a remarkable physiographic feature of the province, where the wide, slow-moving St Lawrence river does not occupy any very distinct channel, but rather flows across a broad, low, hilly region of very moderate relief thus allowing the low rocky hills to stand out as islands.

The rocks are chiefly sandstones and limestones of Cambrian and Ordovician ages, though, in the vicinity of the Thousand Islands numerous patches of the underlying Precambrian (Adirondack) rocks are exposed as on many of the islands themselves. Folds, faults, and igneous rock are not present except in the Precambrian rocks, and the strata may be regarded as a comparatively thin mantle of nearly horizontal layers overlying the Precambrian rocks.

CHAMPLAIN VALLEY PROVINCE

The Champlain valley bounds the Adirondacks on the east. This province should be regarded as a great depression separating the Adirondacks on the west from the Green mountains on the east. Much of the valley bottom is filled by the waters of Lake Champlain (elevation 101 feet). Along the western shores of the lake the topography is characteristically hilly, though seldom above 500 feet in elevation. The transition to the higher and rugged Adirondacks is generally rapid.

The rocks occupying the valley bottom are sandstones, limestones and shales of Cambrian and Ordovician ages. These formations are much disturbed by numerous faults, often of considerable magnitude, and in fact there is good reason to think that the whole Champlain valley is of the nature of a great fault-trough or depression.

HUDSON VALLEY PROVINCE

General description. Looked upon in a broad way, the Hudson valley province is a depression lying between the western highlands of New England and the eastern highlands of New York. Well toward the south the true valley feature is somewhat interfered with by the presence of such elevated masses as Shawangunk mountain and the Highlands-of-the-Hudson. A very detailed classification of topographic features would call for four or five provinces instead of the one here called the Hudson valley province. Since even this southern part, however, is lowland compared with the Catskill mountains immediately westward and since the rock structures are so similar and characteristic throughout the region, though the kinds of rocks vary considerably, it seems best for our purpose to treat all together as the Hudson valley province, and then to describe very briefly each of the minor subdivisions of the province.

The foundation rocks of the whole province comprise various formations of Precambrian, Cambrian, and Ordovician ages, while in a few places mere surface layers of Silurian, Devonian, and Mesozoic strata occur (see geologic map, figure 1). All the rocks, except these few younger surface layers, are highly folded, which constitutes the most characteristic structural feature of the whole province. In fact, as is hereafter shown (see chapter 4), there are here exposed the roots or remnants of a portion of the very ancient Taconic mountain range which at one time occupied this region. Thus from the geologic standpoint, the term Taconic province would be appropriate. All along the border of the province, as well as throughout the Hudson Highlands, the rocks are rather severely metamorphosed.

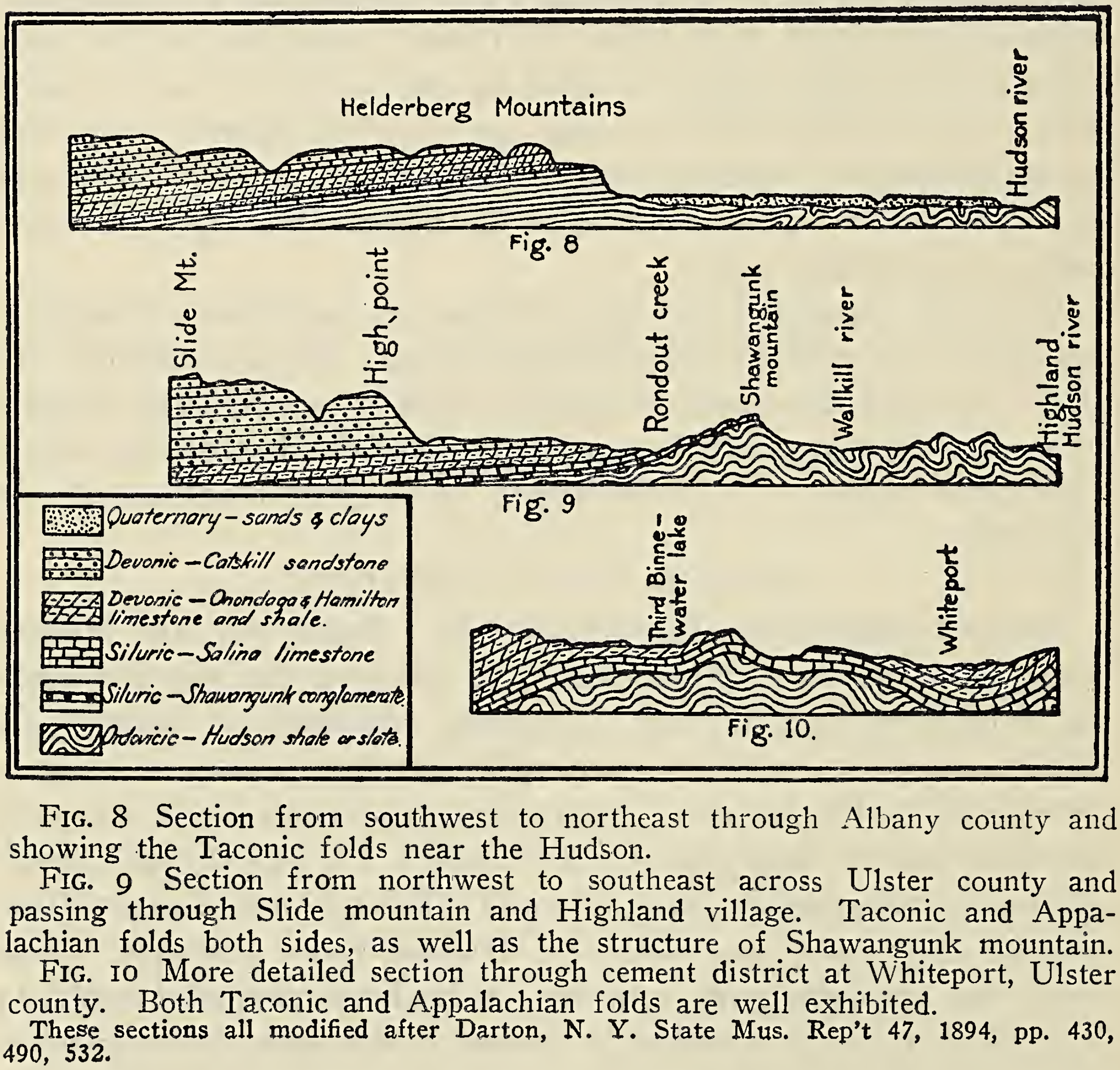
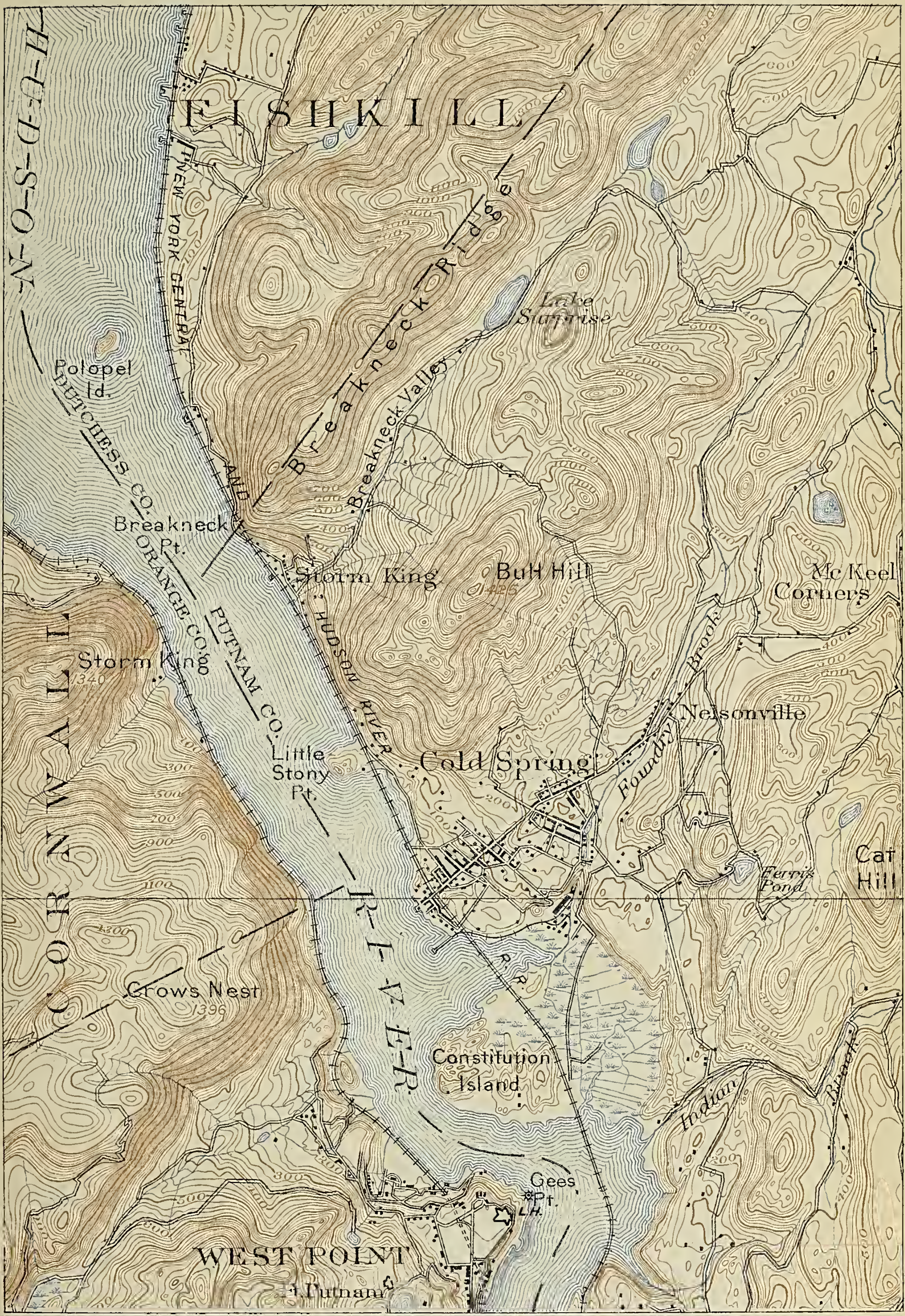

Helderberg Mountains
Hudson river
Fig. 8
Slide Mt.
High point
Rondout creek
Shawangunk mountain
Wallkill river
Highland
Hudson river
Fig. 9
Quaternary – sands & clays
Devonic – Catskill sandstone
Devonic – Onondaga & Hamilton limestone and shale.
Siluric – Salina limestone
Siluric – Shawangunk conglomerate.
Ordovicic – Hudson shale or slate.
Third Binnewater lake
Whiteport
Fig. 10.

FIG. 8 Section from southwest to northeast through Albany county and showing the Taconic folds near the Hudson.

FIG. 9 Section from northwest to southeast across Ulster county and passing through Slide mountain and Highland village. Taconic and Appalachian folds both sides, as well as the structure of Shawangunk mountain.

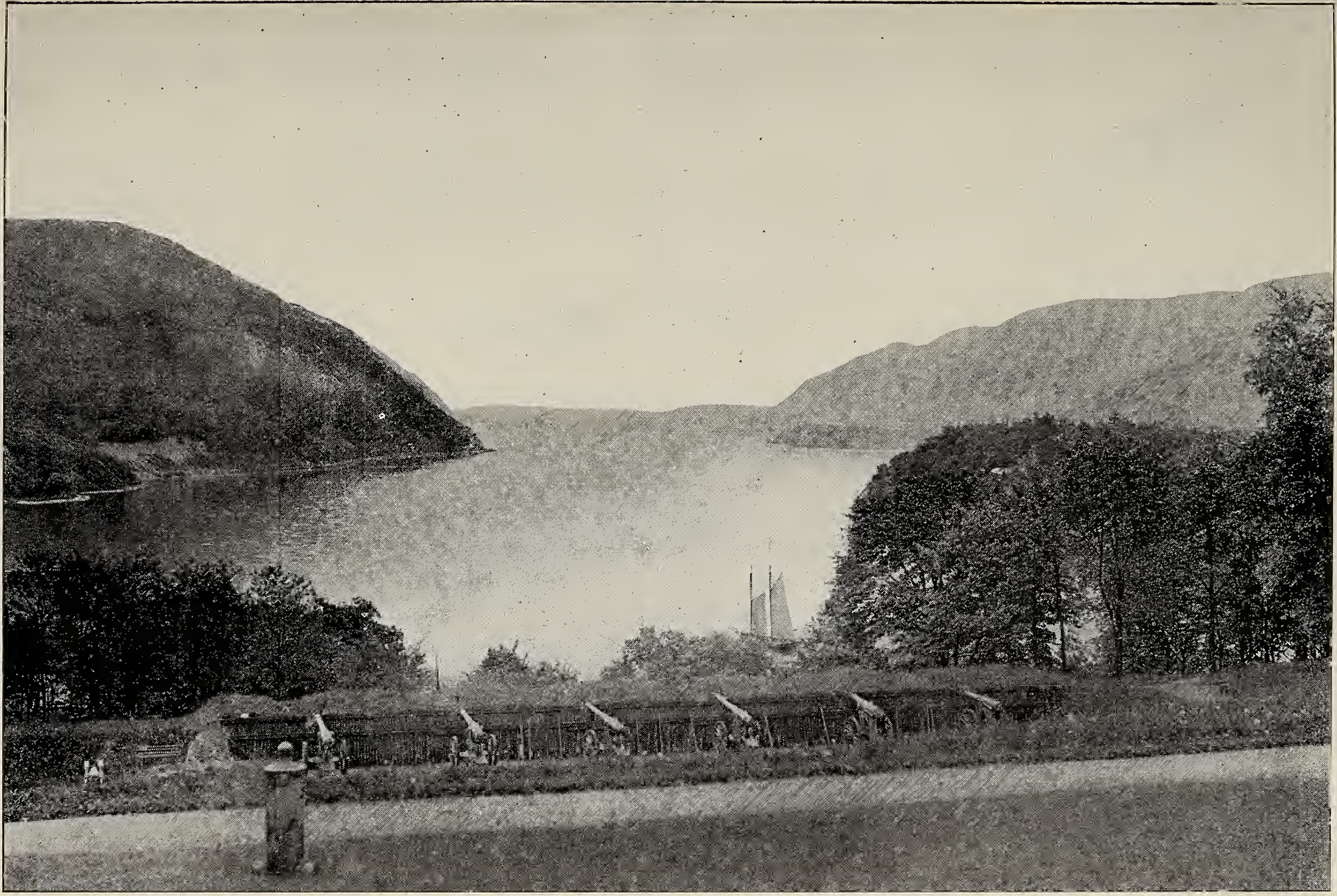
FIG. 10 More detailed section through cement district at Whiteport, Ulster county. Both Taconic and Appalachian folds are well exhibited.

These sections all modified after Darton, N. Y. State Mus. Rep't 47, 1894, pp. 430, 490, 532.



A portion of the West Point (U. S. G. S.) contour map, illustrating the topography of the Highlands of the Hudson. The river here flows through a deep, narrow gorge which has been cut through the northeast-southwest ridges of very hard Precambrian rock. The sides of the gorge rise abruptly from the river to heights of 1200 or 1400 feet, while the rock bottom of the gorge is hundreds of feet below the river level. Scale, about 1 mile to the inch.

Plate 11



Looking north up the Hudson where the river flows through a deep narrow gorge in the hard granitic (Precambrian) rocks of the Highlands. The mountain on the left is Crow's Nest and the nearer one on the right is Bull hill. Each of these mountains rises to more than 1400 feet above the river while the rock bottom of the river is buried some 600 to 800 feet. Compare with plate 20.

From N. Y. State Mus. Bul. 146, pl. 16

Highlands-of-the-Hudson. The Hudson Highlands extend across the Hudson valley in a northeast-southwest direction, and cover southern Orange county and northern Rockland county, and the region from southern Dutchess southward across Putnam and into Westchester county. The relief is rather rugged with the higher points commonly reaching altitudes of over 1000 feet. The rocks are chiefly granites and gneisses of Precambrian age, and they are in most ways much like those of the Adirondacks.

Region north of the Highlands. North of the Highlands the rocks are in the main highly metamorphosed shales, sandstones and limestones, and the relief is generally low except along the eastern border where it is almost mountainous. A characteristic feature along this eastern side is the presence of long, fairly high, nearly north-south ridges separated by comparatively narrow valleys.

Shawangunk mountain. Lying close to the southeastern border of the Catskills and extending northeastward from the State line in Orange county well into Ulster county, is a distinct mountain ridge known as Shawangunk mountain. This long, narrow mountain rises 1000 feet or more above the surrounding country, and with the deep narrow Rondout valley immediately on its west side and the broad, open Wallkill valley on the east, it is truly a remarkable topographic form. The capping of very hard Silurian conglomerate upon the soft Ordovician shales has caused the ridge to stand out boldly against erosion (see figure 9 and plate 28).

Region south of the Highlands. Southern Rockland county is covered by Triassic sandstone. This rock is not folded, and it contains within its mass great sheets of lava which outcrop to form the Palisades along and west of the Hudson (see figure 20).

In southern Westchester county, and in New York county, there are highly folded and metamorphosed Precambrian and Ordovician rocks, and the country is typically hilly.

LONG ISLAND PROVINCE

This province, including Staten Island, is really a part of the broad Atlantic coastal plain, and it is, therefore, practically devoid of any hard rock formations at the surface. Except for a few exposures of Cretaceous sands and gravels along the northern border, the whole province is made up of glacial sands and gravels. From the standpoint of surface relief the province is clearly divisible into two parts, a northern and a southern, which are sharply separated from each other (see plate 12). The northern part is characteristically hilly, the hills being of glacial (morainic) origin. The maximum elevation is less than 400 feet, and in general the hills are from 100 to 200 feet high. This line of hills ends abruptly about midway of the island (north-south), and the southern part of the province is a sand plain of remarkable smoothness with a gentle slope toward the ocean.

DRAINAGE

Considered as a great watershed, New York State takes rank as one of the most noteworthy in the United States. The waters of the State, except for a little in the southeast, enter the sea at five widely separated places, namely, Gulf of St Lawrence, New York bay, Delaware bay, Chesapeake bay and the Gulf of Mexico, through the five well-known rivers, namely, St Lawrence; Hudson, Delaware, Susquehanna and Mississippi (through the Allegheny and Ohio rivers.)

Mohawk-Hudson basin. The principal stream of this, the largest drainage basin of the State, is the Hudson river which is especially noteworthy in two ways, first because it is by far the largest stream whose course is wholly within the borders of the State, and second because soon after emerging from the Adirondacks (near Glens Falls), its course, for nearly 200 miles to its mouth, is remarkably straight in spite of the fact that it traverses the principal structural lines of a highly folded and disturbed region. Its apparently anomalous, deep, narrow, granite-walled channel across the Highlands of the Hudson (see plate 10) is explained in chapter 6. The chief tributary of the Hudson, markedly the Mohawk river, has its headwaters in the very center of the State and reaches the Hudson after flowing eastward for more than 100 miles.

The drainage of the southern Adirondacks, even as far north as Mount Marcy, and also of the eastern Catskills, passes into the Hudson river. Except for very minor contributions from the edge of New England and New Jersey, the whole river system derives its water from within the boundaries of the State.

St Lawrence basin. This drainage basin comprises all the northwestern Adirondacks, and it reaches well into the heart of the mountains. All the larger streams, which are of very moderate size, flow northwestward in remarkably parallel courses until, emerging upon the floor of the St Lawrence valley, they swing around to northeasterly courses and generally flow for a good many miles parallel to the great river itself before entering it. This latter

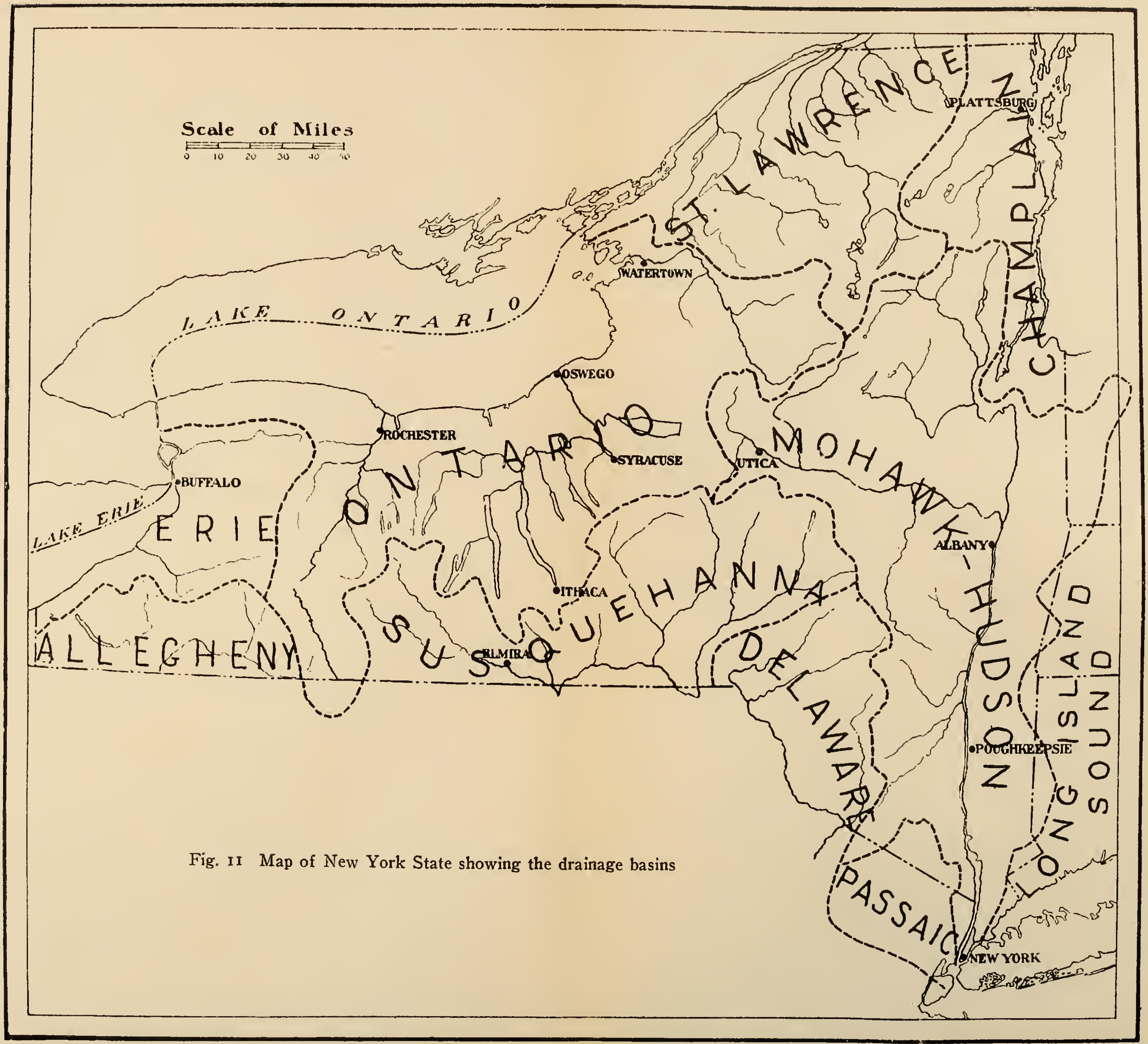


Fig. 11 Map of New York State showing the drainage basins

phenomenon is, no doubt, to be explained on the basis of topographic changes due to the great Ice age. The largest and longest stream in the basin is the Raquette river which, after a devious course of more than 100 miles, including passage through two or three large lakes, enters the St Lawrence at the northern State boundary.

Ontario basin. All the streams of this basin enter Lake Ontario, and they pursue courses that, if continued, would tend to converge at a point in the lake basin. Thus the streams in the western portion of this drainage basin flow north to northeastward, northward in the middle portion, and westward to northwestward in the eastern portion. Three rivers should be mentioned: the Genesee, with its source in the highlands of Pennsylvania, flows northward across the entire southwestern plateau; the Oswego, toward the middle of the basin, receives one branch (Seneca river) from the west, draining the large Finger lakes, and another branch from the east, draining Oneida lake and part of the Tug Hill plateau; Black river drains the extreme eastern portion of the basin, and a number of prominent tributaries flow southwestward from well within the Adirondacks to join the main stream in the Black river valley.

Susquehanna basin. All the waters of the Susquehanna river are derived from the Southwestern plateau. The main stream (within New York) flows southwestward and together with its numerous large tributaries, drains much of the eastern portion of the plateau region, especially in Otsego county. A number of the tributaries rise on the very crest of the Helderberg escarpment, within a few miles of the Mohawk river. The Mohawk river is fully a thousand feet below the crest of the escarpment, and its course is at right angles to that of Susquehanna tributaries.

The Chemung is the principal tributary from the northwest, and it drains a good portion of the south-central plateau.

Other drainage basins. The Champlain basin comprises the eastern border of the Adirondacks, including some of the highest and most rugged of those mountains. Nearly all of the streams are short, and most of them descend eastward very rapidly into Lake Champlain.

The Delaware, by means of its upper waters, drains the western and southern Catskills and the main stream, after flowing southeastward along the State line between New York and Pennsylvania, from Delaware county to Orange county, suddenly swings southwestward to pass through the famous Delaware water gap in the Kittatinny range.

The Allegheny river sends out a number of small branching arms to drain the extreme southwestern portion of the Southwestern plateau. Chautauqua lake (elevation 1338 feet) which lies at the very western edge of the plateau close to Lake Erie, has its outlet into the Allegheny.

The Erie basin contains no river of much consequence, the small streams all flowing westward or northwestward across the narrow Erie plain into Lake Erie or the Niagara river. Nearly all of these streams rise along the western edge of the Southwestern plateau.

In quantity very little of the water of the State enters the Long Island sound basin, a few small streams north of the sound together with the numerous but very small streams of Long Island comprising the whole supply.

The Passaic basin is mostly confined to New Jersey, with a few small streams having sources in Rockland and Orange counties.

Chapter 3

PRECAMBRIAN HISTORY

THE GRENVILLE FORMATION

In the Adirondack mountains, and also probably in the Highlands-of-the-Hudson, we have the earliest known records of the physical history of New York State. These records are written in a series of rocks named the Grenville, so called from a town in Canada where the rocks were first well known. The Grenville is of interest, not only because it is the most ancient rock formation so far discovered in New York, but also because it takes rank among the very oldest rock formations of the earth.

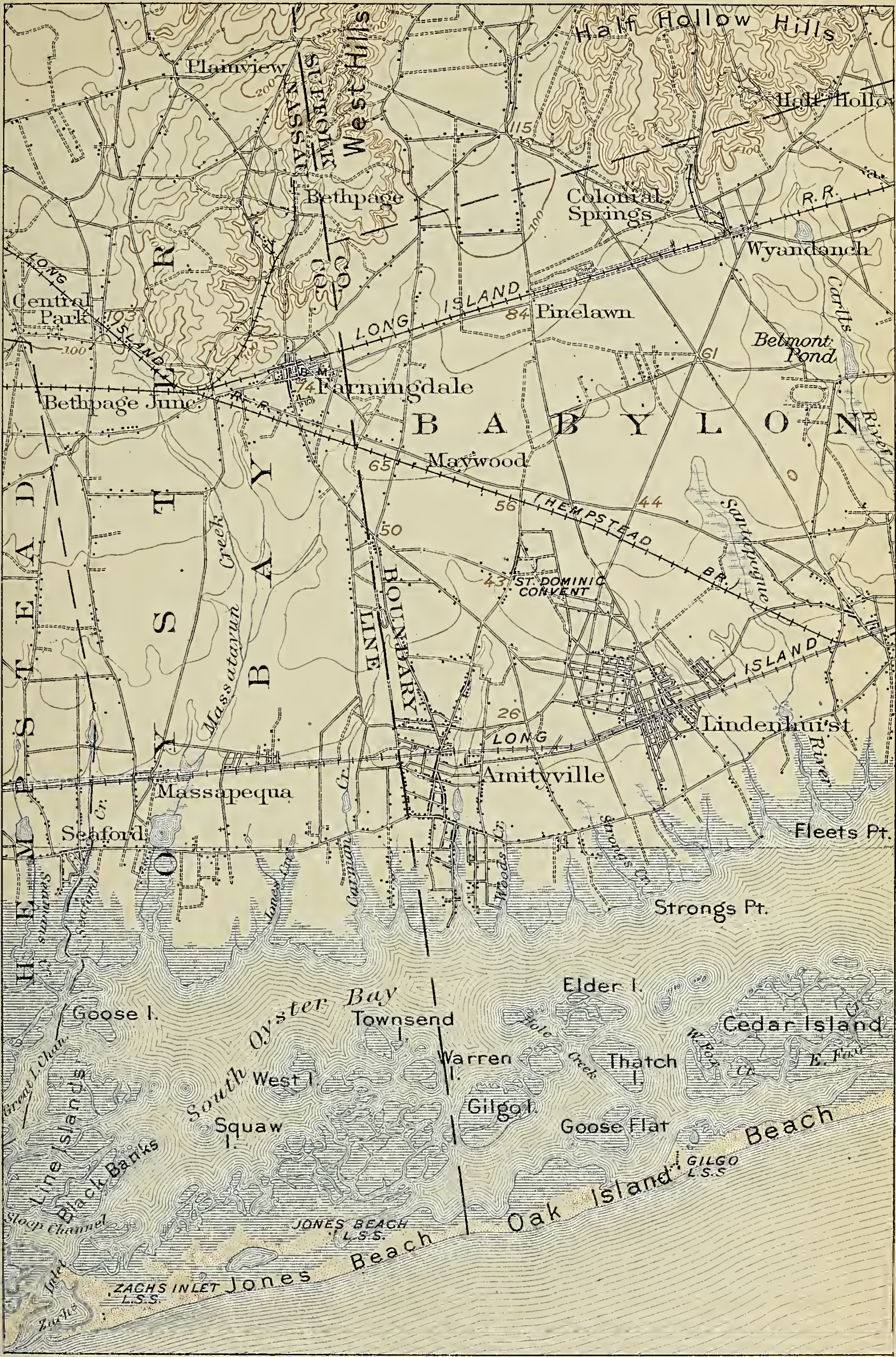
Until about fifteen or twenty years ago the real significance of the Grenville and its closely associated rocks in the Adirondacks was not recognized, but now many of the leading events of that very early history are established. As in human history, so in earth history, the earliest records are the most obscure and difficult to read and, in the one as in the other, it is easy to pass from conclusions properly based upon facts to mere speculations. Various problems regarding the Precambrian history of our State yet remain to be solved, but in these pages it is rather the purpose to describe only those historical events which have been reasonably well established.

The Grenville consists of a great series of marine water-laid rocks which are clearly older than the Paleozoic because these latter rest upon the Grenville in many places. As will be shown below, the Grenville strata have been so profoundly changed from their original condition that certain of the highly sedimentary features have been obliterated. Thus the absence of water-worn particles and fossil shells, both of which are so characteristic of sedimentary deposits, is due to complete crystallization (metamorphism) of the Grenville strata since their formation. Nevertheless we have certain proofs of the sedimentary origin of the Grenville. The fact that these rocks commonly occur in alternating layers, which stand out in sharp contrast because of marked difference in composition and color, furnishes strong evidence that this distinct banded effect is due to differences in original sedimentation. A great mass of igneous rock is generally characterized by homogeneity throughout; a mass of typical sediments, on the other hand, is arranged in distinct layers, such as shale, sandstone, or limestone which show frequent differences in composition. In the Grenville, especially of the northwestern and southeastern Adirondacks, there are extensive beds of crystalline limestone, such as the Gouverneur marble of St Lawrence county. Such rocks could not have been of igneous origin. In many places, and sometimes in sharp contact with the limestone, are beds of almost pure quartz rock, which are certainly not igneous but which represent original sandstone layers. Another argument in support of the sedimentary character of the Grenville is the presence of flakes of graphite (plumbago) which are so commonly disseminated throughout the formation. In some places the strata are so filled with graphite that the mineral is mined, as in Essex and Saratoga counties. Carbon existing under such conditions is probably of organic origin and represents the final stage in the decomposition of organisms which lived in the waters while the Grenville strata were being deposited.

Having established the sedimentary origin of the oldest known formation in New York State, we are led to the interesting and important conclusion that this Grenville formation is not the oldest which ever existed in the State. The Grenville sediments must have been deposited, layer upon layer, upon a surface of still older rocks. A knowledge of the character and composition of such Pregrenville rocks would be of very great interest, but thus far we have no positive evidence that such rocks are visible in the Adirondacks, although certain rocks still of somewhat doubtful age and origin may belong to that very ancient rock floor. Again, the fact that Grenville sediments were being deposited under water carries with it the corollary that there must have been land somewhere at no great distance from the area of deposition because then, as now, such sediments as muds and sands could have been derived only from the erosion or wearing away of land and have been deposited in great sheets one above the other, under water adjacent to the land mass. Here, too, we are as yet utterly in the dark so far as any knowledge of the location or character of that very ancient land is concerned.

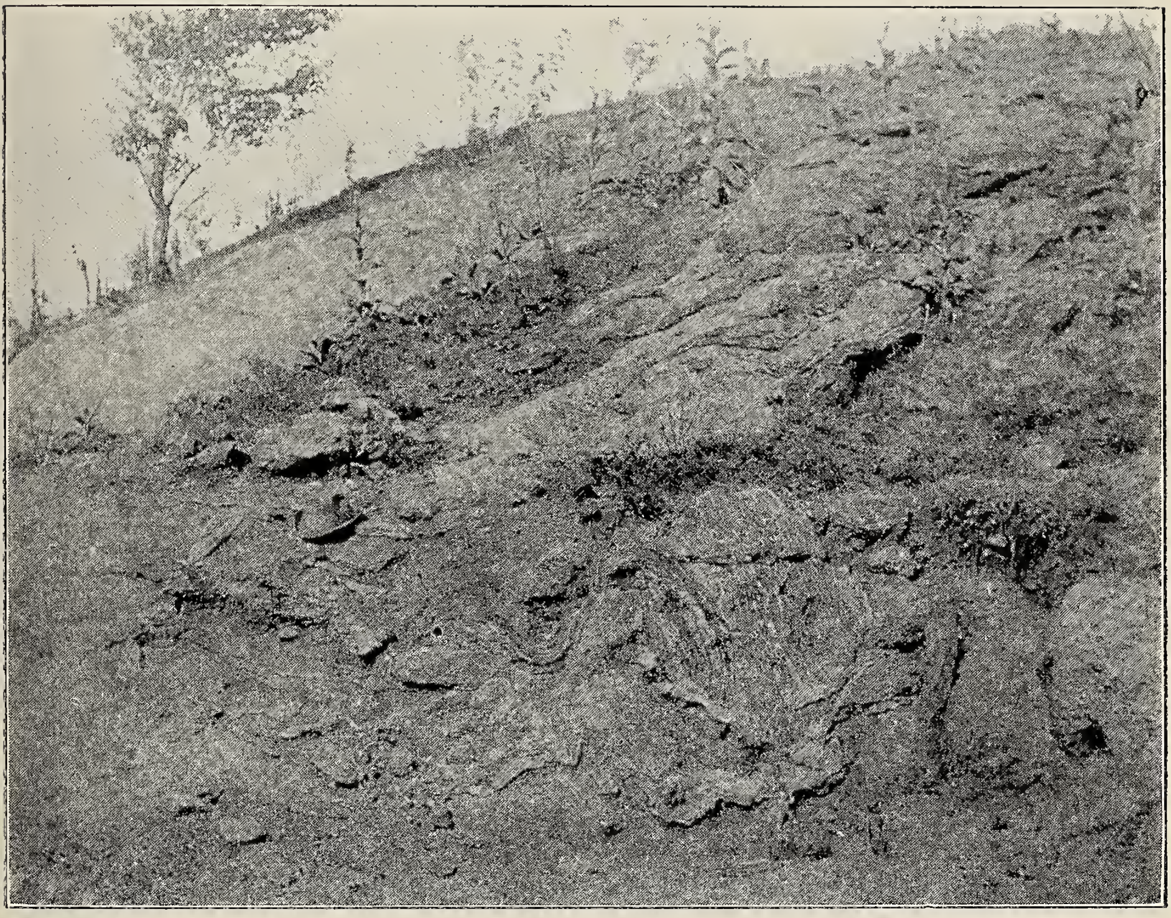
DISTRIBUTION, THICKNESS AND AGE OF THE GRENVILLE

The Grenville is associated with rocks of younger age in the Adirondack region, so that the formation is not present as a single, continuous mass of surface rock covering the whole area. It is, however, so abundant and widespread in great and small areas throughout the Adirondack province that we may confidently assert



A portion of the Islip (U. S. G. S.) quadrangle showing typical Long Island topography. Note the distinct hills (of glacial morainic origin) on the north, the perfect plain only very slightly stream-dissected and with very gentle seaward slope, and the long beach (built by wave action) inclosing the shallow bay with its many swampy islands. Scale, about 2 miles to the inch.

Plate 13



An outcrop of typical Grenville (Precambrian) limestone showing the folded or contorted and streaked character of the rock. View taken 1½ miles southeast of Johnsburg, Warren county.

W. J. Miller, photo

that this whole district was under water during Grenville time. As the geologic structure strongly suggests, and as certain deep wells prove, rocks of this age must extend, under cover of the later Paleozoic sediments, for a considerable distance beyond the Adirondack area. Precambrian rocks have long been recognized in the Highlands district of the lower Hudson including New York City and vicinity and recent work makes it practically certain that strata of Grenville age exist there. Precambrian (doubtless including Grenville) occurs along the western border of New England, and it should also be mentioned that Grenville strata are extensive over much of southeastern Canada. Presence of Grenville strata in southwestern New York is somewhat doubtful because, if there, they are effectually concealed under the heavy cover of Paleozoic strata. The positive existence of Grenville, however, just to the north in Canada and in northern and southeastern New York, makes it more than likely that the Grenville underlies the Paleozoic rocks of western New York also. Such a widespread distribution of the Grenville sediments shows that deposition went on in a very large body of water; large enough, in fact, to be called an ocean. *Thus, bearing in mind all the facts, we are led to the important conclusion that, during Grenville time, all of northern and eastern, and probably also southwestern New York was under the sea. In other words, the most ancient known geographic condition in New York was a great expanse of ocean water covering most, if not all of the State.*

Since the rocks are badly disturbed and folded, and since neither top nor bottom of the formation has been recognized as such, it is impossible to give anything like an exact figure for the thickness of the Grenville rocks. Continuous successions of strata have been observed in enough places, however, to make it certain that Grenville strata were piled, one layer upon another, to a thickness of thousands of feet. This clearly implies that the Grenville ocean existed for a vast length of time which must be measured by no less than a few million years, because in the light of all our knowledge regarding the rate of deposition of sediments, such a very long time was necessary for the accumulation of so thick a mass of rocks. It does not necessarily follow that the Grenville ocean was thousands of feet deep when the deposition began, because there may well have been a gradual subsidence of the sea floor during the process of sedimentation, which means that there was not necessarily very deep water at any time. In fact, the very character of the sediments clearly indicates that the Grenville ocean was, for most part at least, of shallow water, for such sediments as sands and muds have rarely if ever been carried far out into an ocean of deep water. The great ocean abysses of today are not receiving any appreciable amount of land-derived sediments. Hence it is practically certain that the very ancient Grenville sea bottom gradually settled as the sediments accumulated. Similar phenomena are definitely known to have occurred in many later basins of deposition.

The reader may naturally be disposed to ask, How long ago did the Grenville ocean exist? There are grave difficulties in the way of answering this question in terms of years, as we have nothing like an exact standard of this kind for comparison. While it is fully recognized that not even approximate figures can be given, a very conservative statement would ascribe an age of at least forty million years to the Grenville strata. Whatever its exact duration may have been, the time is utterly inconceivable to us, and the important thing to bear in mind is that the great events of earth history which have transpired since the Grenville deposition require a lapse of many million years as shown by the enormous accumulations of sediments in many parts of the earth, and by the building up and wearing away of one great mountain range after another. The reader will better appreciate the significance of these statements after he has studied the following pages. In the table of geological time divisions given in chapter 1, the two oldest periods are the Archean and Algonkian respectively. The Grenville can not with certainty, as yet, be placed in either of these periods, although according to the best evidence it should be classed with the Archean. In the meantime it is advisable to refer to all formations older than the Paleozoic simply as Precambrian.

LIFE IN THE GRENVILLE OCEAN

All that can be said regarding the life of the Grenville ocean is that it existed as indicated by the presence of the graphite. Although we can not even state whether the organisms were plant or animal, the fact that there was life in that very ancient ocean is a matter of no little significance. Anthracite coal, which is chemically very similar to graphite, occurs in the Carboniferous strata of Pennsylvania, and it is derived from plants through the process of carbonization. Graphitic anthracite of like origin occurs in a smaller way in Rhode Island. Hence it seems likely that the graphite of the Grenville represents the remains of plants, probably of the seaweed type since there is much evidence against the view that any of the higher land plants existed at that very early time. This by no means proves the absence of animals from the Grenville ocean, because animals with only soft parts would have left no record, while calcareous or silicious shells would doubtless have been recrystallized by the severe processes of metamorphism to which these rocks have been subjected.

EARLY PRECAMBRIAN IGNEOUS ACTIVITY

After the accumulation of the Grenville sediments, igneous activity took place on a large scale, when great masses of molten rock were pushed or intruded into the sediments from below. Several different times of igneous activity have been definitely recognized and the general effect of the great invasions of molten rocks was to break the Grenville up into patches. In many cases considerable masses of Grenville were pushed aside or displaced by the molten masses while, to a greater or less extent, there may have been an actual melting in or assimilation of Grenville rocks by the molten intrusions. As we have already learned, igneous rocks are those which have cooled from a molten condition, and of these there are two important types, called respectively, plutonic and volcanic. In the strict sense of the term, there are no volcanic rocks in the Adirondacks, but the plutonic rocks are very prominently developed.

So far as we know, the first great intrusion of molten rock in the Adirondacks is represented by the present large area of so-called anorthosite in Essex and Franklin counties. This is a very coarse-grained, plutonic rock of bluish gray color when fresh and consists chiefly of a feldspar (labradorite). The intrusion was largely confined to a single area comprising about 1200 square miles. That this rock is younger than the Grenville is demonstrated by the fact that tongues of the anorthosite have been observed cutting through the Grenville (see figure 12). In a few cases small patches of Grenville were caught in the molten flood of anorthosite and now may be seen within the anorthosite mass. For the most part, however, the molten rocks either completely pushed aside the Grenville or melted it into itself, the former being the more likely. Many of the highest points within the Adirondacks, such as Mt Marcy and Mt Whiteface, are in this anorthosite area.

Another kind of plutonic igneous rock in the Adirondacks is so-called gabbro. It is a medium-grained nearly black rock. It occurs in numerous relatively small areas throughout the region. Most of this gabbro is known to be younger than the Grenville strata because it has been intruded into them. It is known to be older than the syenite-granite series (next described) because it has been intruded and more or less cut to pieces by the great, once molten bodies of the syenite-granite. The age relation of the gabbro to the anorthosite has not yet been definitely determined.

The next clearly recorded event, after the anorthosite and gabbro intrusions, was very widespread igneous activity when the rocks of the granite-syenite series, now so well known in the Adirondacks, were forced upward into the older rocks. Granite is a plutonic, igneous rock which consists essentially of quartz and feldspar (orthoclase), together with more or less black mica, hornblende, or augite. Syenite is the same except that quartz is much less prominent, or lacking. The fresh rock is of a greenish gray or pinkish gray color, while on weathered surfaces the color is usually light brown. Many of the highest mountains outside the anorthosite area are of granite or syenite.

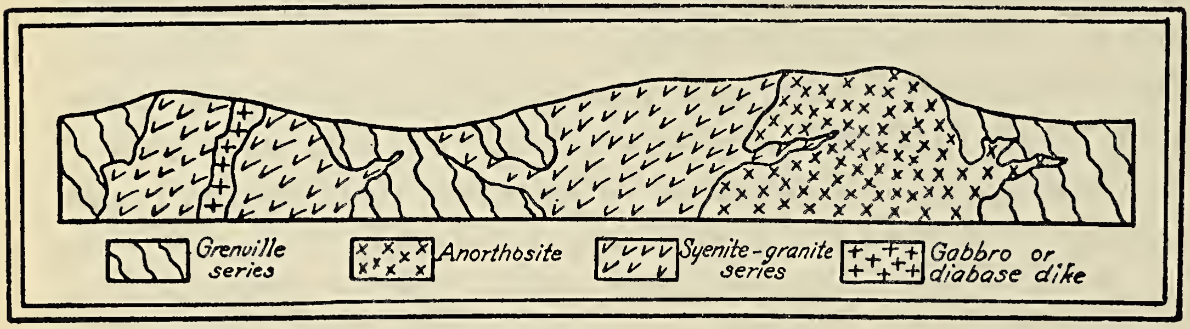
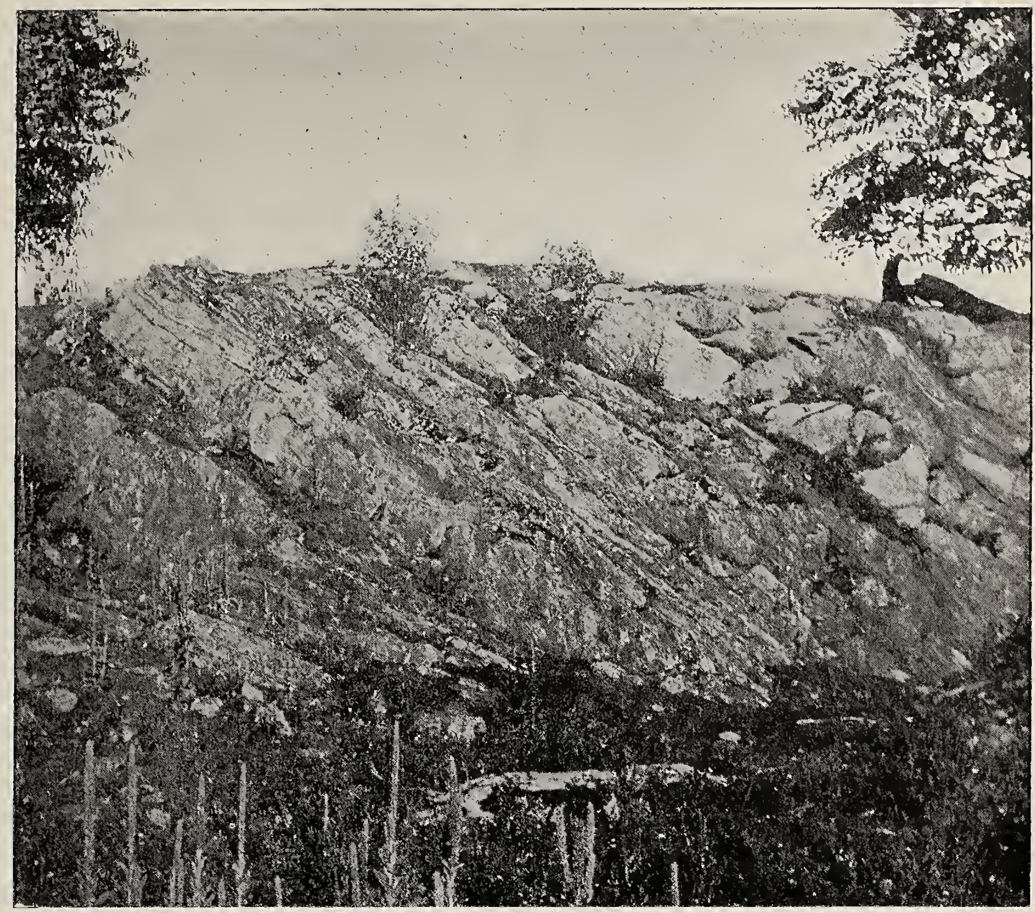
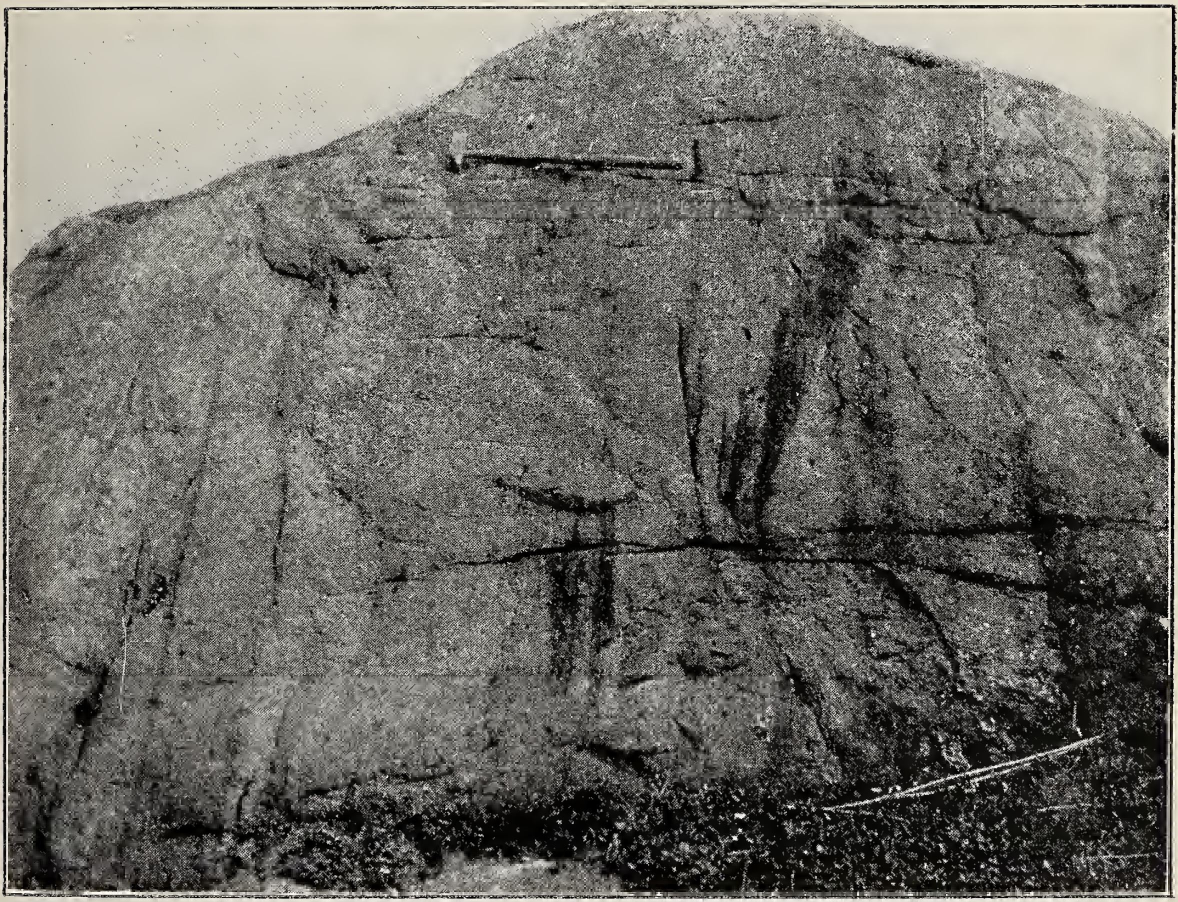


Fig. 12 Generalized section showing the relations of the most common Precambrian (Adirondack) rocks to each other and how their relative ages are determined.

The present distribution of these rocks shows that the molten masses broke into the Grenville anorthosite and gabbro in very irregular fashion, sometimes pushing the older rocks aside; sometimes enveloping great or small masses of the older rocks within the molten flood; sometimes intimately injecting the Grenville and gabbro, and in other cases, apparently leaving large masses intact. All portions of the Adirondacks felt the force of the intrusions and a detailed geologic map of the region would show a decided patchwork effect (see figure 13) due to the irregular manner in which the Grenville and gabbro have been cut up by the igneous rocks.



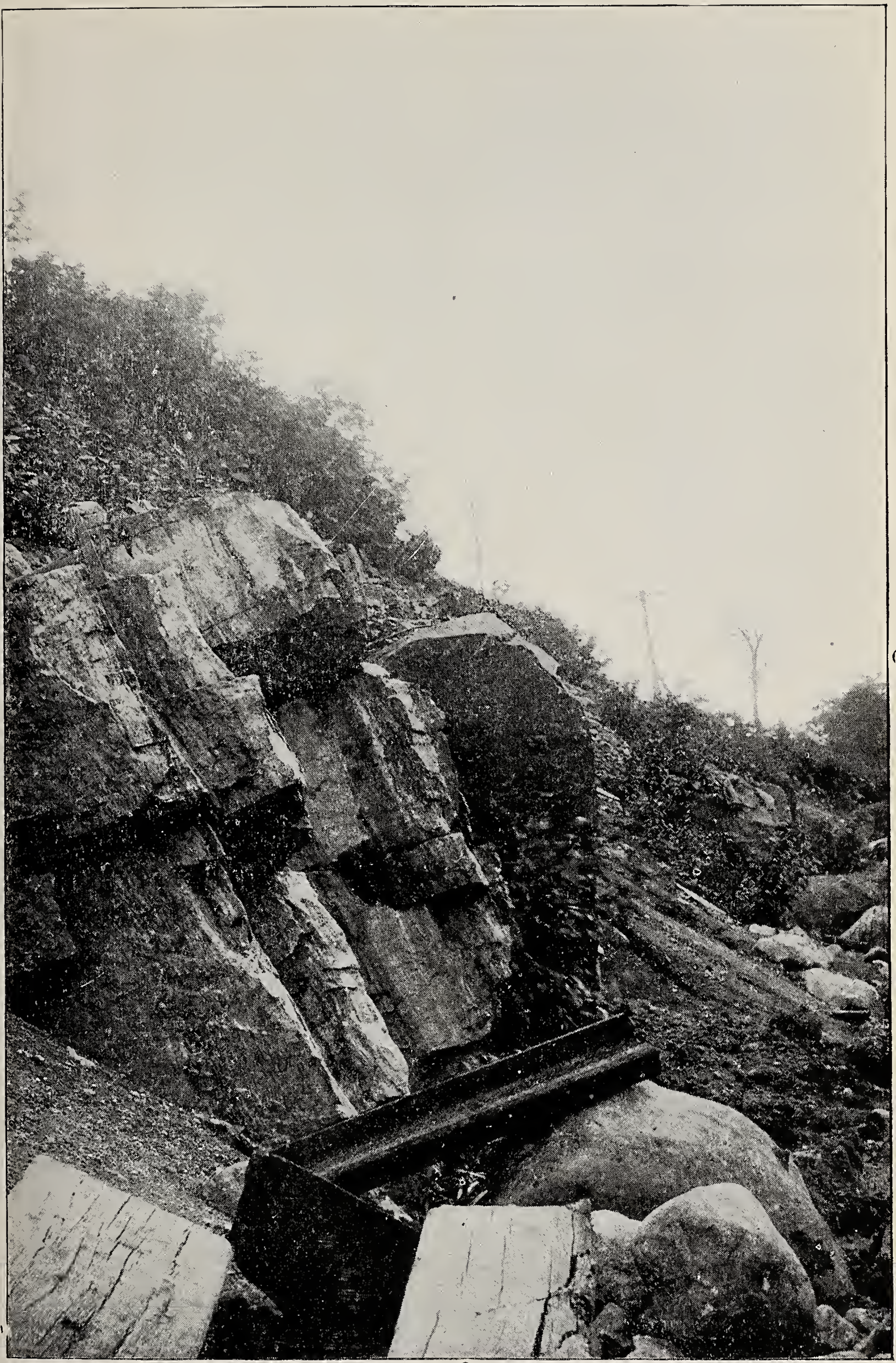


Upper figure. Typical outcrop of Adirondack Grenville gneiss, showing distinct stratification and tilted beds. Three-quarters of a mile north-northeast of Batchellerville, Saratoga county.

From N. Y. State Mus. Bul. 153, pl. 1

Lower figure. Typical outcrop of Adirondack syenite (igneous rock) at Harrisville, Lewis county.

From N. Y. State Geol. Rep't 1897, facing p. 470



A ledge of Precambrian rock near Loon lake in the northern Adirondacks, showing the very ancient Grenville gneiss in sharp contact with syenite. The light and dark banded rock on the right is Grenville and the hammer is on the contact.

From N. Y. State Mus. Bul. 5, pl. 3

These igneous rocks are generally easily distinguished from the old sediments because of their homogeneity in large masses and lack of sharply defined bands of varying composition.

That these granite-syenite rocks are younger than the Grenville, anorthosite, and gabbro is demonstrated by the fact that tongues of the former have been observed to cut the latter (see figure 12). Since the granite and syenite now visible in the Adirondacks are plutonic rocks, they could not have reached the surface by intrusion, as such rocks can be formed only by slow cooling under great pressure thousands of feet below the earth's surface. They now appear at the surface because of vast removal, by erosion, of the overlying original materials.

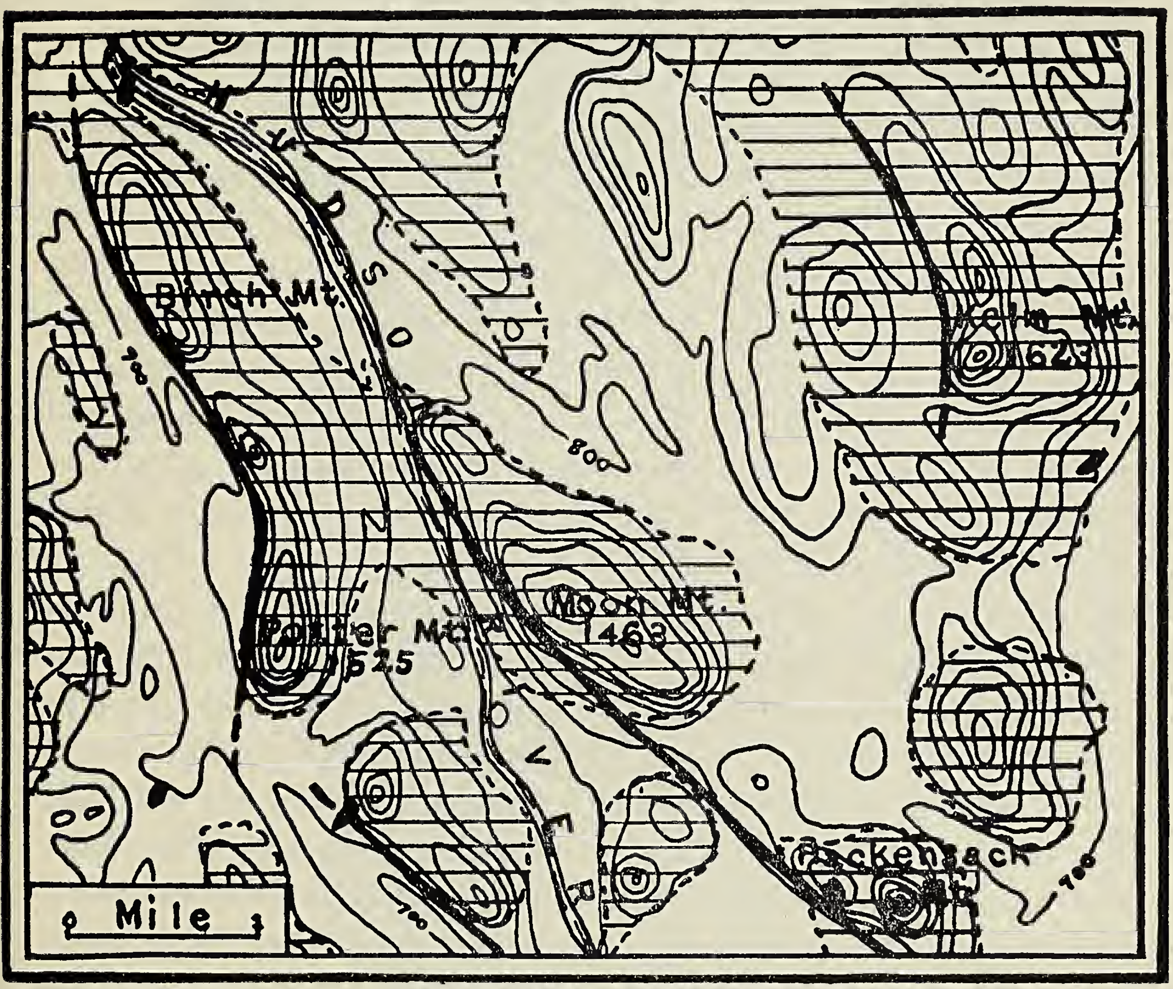


FIG. 13 Geologic and topographic sketch map of the southeastern portion of the North Creek sheet (Warren county), showing the surface relations of the common Precambrian rocks in the southeastern Adirondacks. Contour interval 100 feet. Horizontally lined areas=syenite or granite; blank areas=chiefly Grenville; small heavy black lines are faults. The faults here shown are minor ones which do not follow the NE-SW trend of the major faults of the eastern Adirondacks. The so-called "patch-work" effect is well shown. Note how the more resistant rocks form the mountains which rise above the general level of the Grenville. (W. J. M.)

It should be stated that this period of igneous activity is by no means confined to the Adirondacks. Similar intrusions are known in the Highlands-of-the-Hudson and also in Canada. The covering of Paleozoic strata in southwestern New York prevents direct observation, but all things considered, it is more than likely that much or all of that part of the State stripped of the Paleozoics, would also show Grenville and other old rocks cut up by granite and syenite.

PREPALEOZOIC DEFORMATION AND UPLIFT OF THE ADIRONDACK ROCKS

During or possibly after these great periods of igneous activity, the whole Adirondack region was subjected to considerable pressure as a result of which the rocks were more or less deformed. The Grenville strata now seldom lie horizontally but they are usually tilted at all sorts of angles, and even the igneous rocks thus far described, show unmistakable evidence of having been subjected to pressure because the minerals are usually flattened out or arranged in parallel fashion, often exhibiting a crude, banded structure. Rocks which have thus been changed are known as gneisses which may be either igneous or sedimentary.

The Grenville sediments were completely crystallized as a result of this metamorphism so that all beds of limestone were converted into marble, sandstone into quartzite, and the shales into gneisses of varying character. Thus the Grenville strata have been very greatly altered from their original condition, which explains why they do not look like the more typical and familiar sediments of later age. The manner in which the Grenville strata, especially the limestones, were locally deformed shows that the rocks must have been in a more or less plastic condition when the pressure was exerted (see plate 13). Heat and moisture, no doubt, aided in this process which we call metamorphism. Such a process can take place only at thousands of feet below the surface of the earth where the rocks, under the enormous weight of overlying material, would act like plastic masses when subjected to pressure within the earth.[1]

Rocks at the surface of the earth, subjected to considerable pressure, would be broken or fractured instead of bent or folded. It is not the present purpose to discuss the origin of such pressure within the earth's crust but suffice it to say that it was probably partly due to shrinkage of the earth and partly to the crowding action of the great bodies of intruding molten materials.

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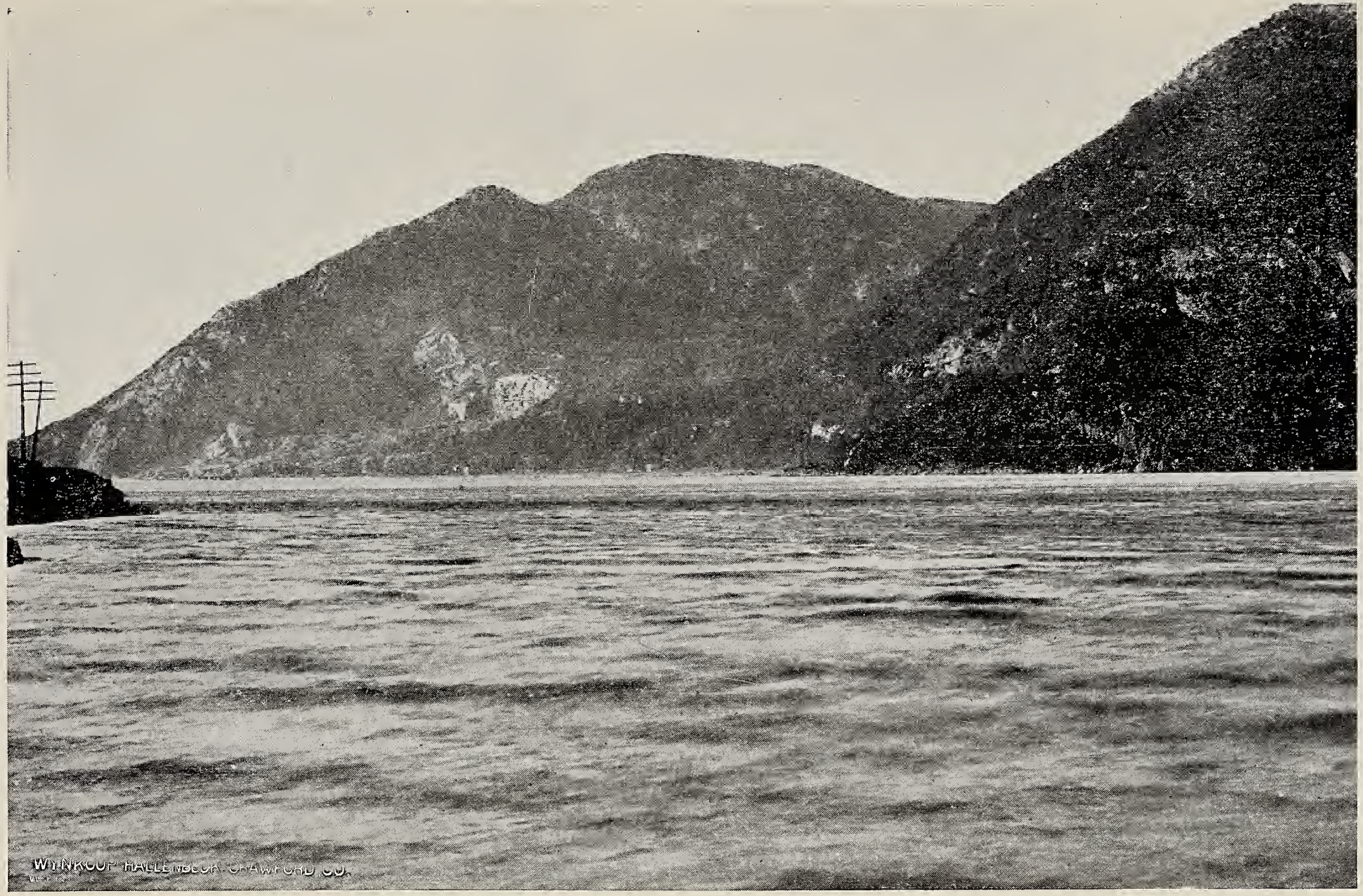
[1] Professor Adams of McGill University, Montreal, has recently proved experimentally that rocks, under great pressure, flow like plastic matter.

Plate 16



View of Breakneck mountain where the Hudson river cuts across the Highlands. Seen from the shore opposite Cold Spring, Putnam county. The rock is Precambrian granite. Back from the river, in these mountains, the character of the topography is much like that of the Adirondacks.

From N. Y. State Mus. Bul. 19, pl. 11

We are now ready to discuss the first known uplift of the whole Adirondack region above sea level, or what we may call the birth of the first known Adirondack mountains. As we have just learned, the very character and structure of the rocks now exposed in the region, show conclusively that they were at one time deeply buried under thousands of feet of overlying materials, and the inference is perfectly plain that those materials must have been removed by erosion. Extensive erosion of any land mass means that the land must be above sea level, and thus we come to the important conclusion that *the great mass of Grenville sediments and associated rocks were upraised well above sea level.* Just when the great uplift occurred can not be positively stated, but if it was not during, or after the igneous intrusions, it must have been shortly before them. It is quite reasonable to believe that the same great force which caused a welling up of so much liquid rock might easily have caused a decided uplift of the whole region. Another view is that a lateral pressure, once started, first caused a welling up, at different times, of igneous rock and then, after the cessation of the igneous activity, the same force continued to squeeze and alter the rocks. Whatever the actual history may have been, it is at least true that the sum total of all effects, as we now observe them, harmonizes well with the view first expressed. We can not, however, state even the approximate height of those very ancient Adirondack mountains. The fact that many thousands of feet of materials have been removed by erosion in order to expose the present rocks to view does not necessarily imply that the mountains at any time had so great a height because it is possible that, while elevation slowly progressed, material was steadily being removed by the process of erosion. All our knowledge regarding later and better known mountains, however, leaves little doubt that those first Adirondacks were mountains much higher than those of today.

The same sort of uplift and succeeding profound erosion also affected the present region of the Hudson Highlands (see figure 14) and, this being the case, we can state with confidence that much, if not all, of northern and eastern New York was involved in this mountain-making process. For western New York the physical geography of this time has not been determined because all that region is so deeply buried under the Paleozoic strata.

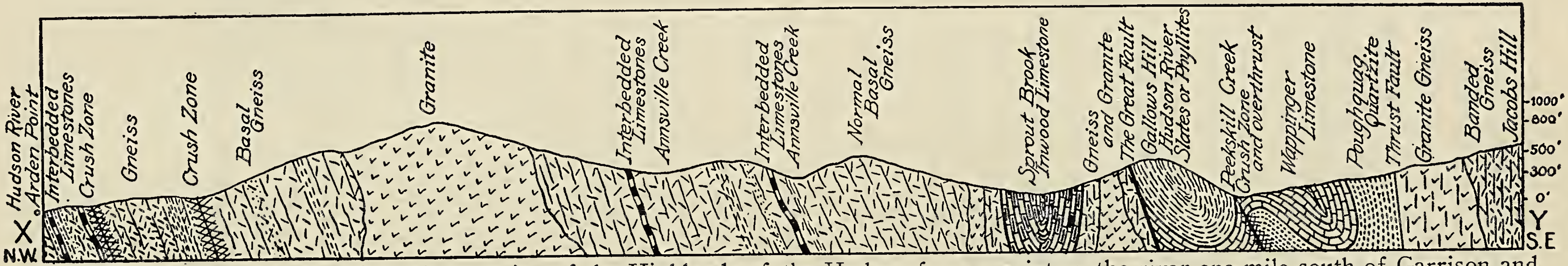
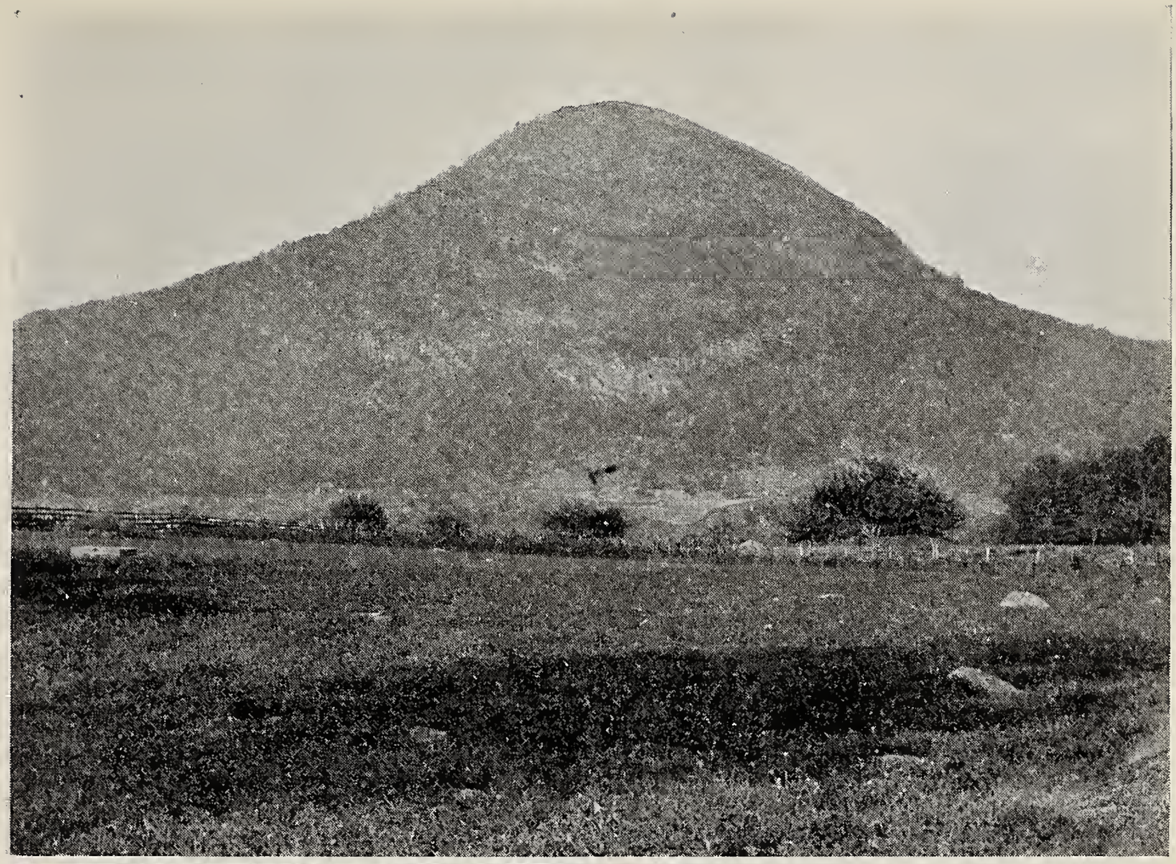
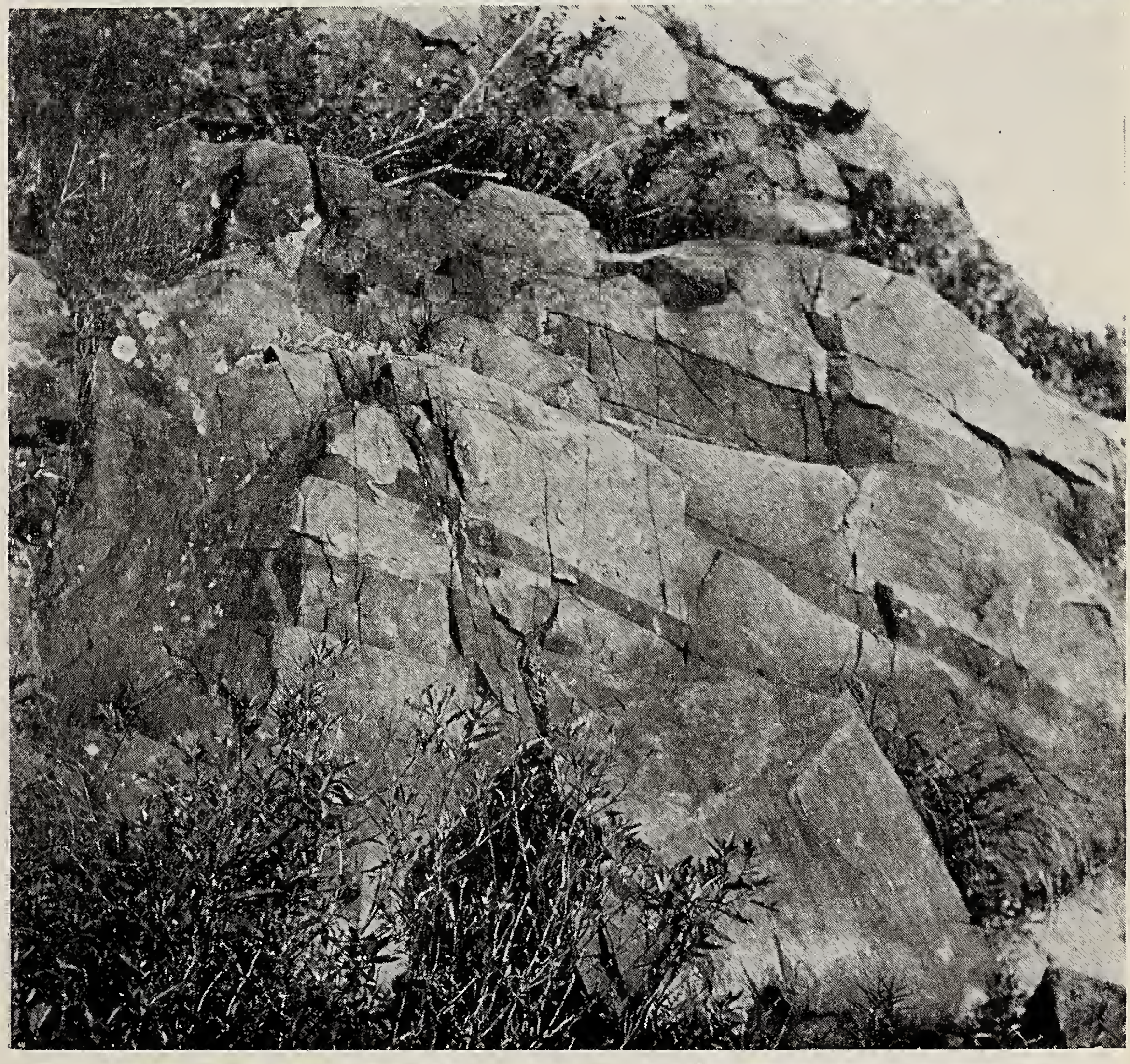


FIG. 14 Structure section through a portion of the Highlands-of-the-Hudson from a point on the river one mile south of Garrison and extending 6 miles southeasterly to Jacob's hill. The basal gneisses are highly metamorphosed and folded Precambrian (Grenville?) sediments through which large masses of granite were intruded. Toward the right are closely infolded belts of early Paleozoic sediments.

After C. P. Berkey, N. Y. State Mus. Rep't 60, v. 2. 1906. p. 371





The upper view is of Potash mountain, locally called the "Potash Kettle," three miles north of Luzerne, Warren county. It is a remarkable feature of the landscape, the almost isolated mountain towering 1100 feet above the surrounding valleys. The rock is Precambrian granite.

The lower view shows several dark lava (diabase) dikes cutting gray syenite three-fourths of a mile northwest of Northville, Fulton county. Both rocks are of Precambrian age.

Photos by W. J. Miller

LATE PRECAMBRIAN HISTORY

The fact that such a great thickness of rock was removed by erosion implies a vast length of time for the accomplishment of that work. According to all that we know regarding the rates of erosion of mountains of the present and past, the erosion of the Adirondacks must have extended over a period of at least several million years. When we consider that, by the opening of Upper Cambrian time, most of the region had been worn down to the condition of a peneplain (see page 43), we are confident that no small amount of the erosion was accomplished even before the opening of the Paleozoic era, and that it continued well into that era. The whole problem of this later erosion and its effects will be treated in the next chapter.

Well toward the end of Precambrian time, igneous activity of a minor character took place in the formation of dikes which, as we have learned, are fissures in the crust of the earth which have been filled with molten rock. In the Adirondack region these dikes consist mainly of diabase which is a fine-grained rock much like ordinary basaltic lava. These dikes are generally less than a mile long and comparatively narrow. That they are younger than the other igneous rocks of the region is abundantly proved by the fact that they cut through those rocks in many places (see plate 17 and figure 12). The fine-grained texture of these rocks, often with borders of glass, shows that they must have cooled close to the surface, and hence it is evident that most of the Precambrian erosion of the region had been accomplished before the diabases were erupted. Such rocks suggest that there may have been volcanic activity at the surface but no positive proof for such activity can be given because, if such volcanic material ever existed, every trace of it has been removed by erosion.

Chapter 4

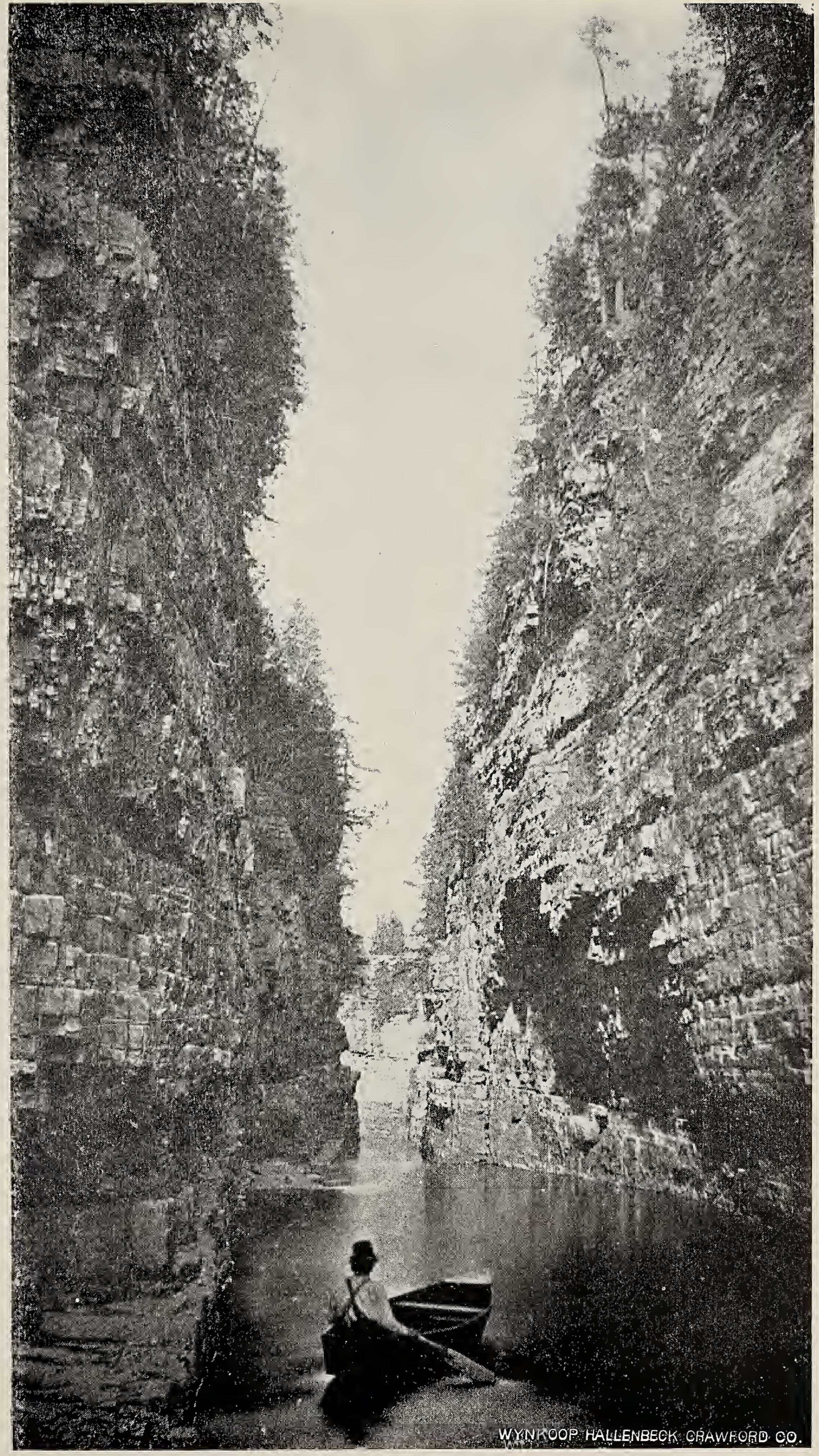
PALEOZOIC HISTORY

CAMBRIAN PERIOD

In the preceding chapter we have seen that after the first known great Adirondack uplift the whole region, including the district of the Highlands-of-the-Hudson, was profoundly affected by erosion, and that this erosion began before the Paleozoic age and extended well into the early part of that era. Now the question may be fairly asked, What became of the sediments which were derived from the wearing down of the land during that vast length of time? We must admit that, in our present state of knowledge, we can not be certain as to what became of the Prepaleozoic sediments. They may have washed westward or southwestward into waters which might possibly have existed there; or they may have been carried northward or northwestward into Canada to help build up late Precambrian deposits there; or they may have moved eastward toward or into the Atlantic basin. The question of the disposition of the early Paleozoic sediments, however, can be much more satisfactorily answered. Early and Middle Cambrian deposits are extensively developed in the New England states, and along the eastern border of New York State, including the Hudson Highlands region. Thus we have positive proof of the presence of the early and Middle Cambrian sea over this region, and it is equally evident that much of this sediment which deposited in the sea was derived from the adjacent land masses in northern and eastern New York.

It was not until the opening of the Upper Cambrian (Potsdam time) that any considerable portion of New York State was occupied by Paleozoic sea water. The fact that all the Cambrian strata, including Lower, Middle, and Upper, are present in the New England country, and along the eastern border of New York, while only the Upper Cambrian is present in northern New York, clearly shows that the Cambrian sea encroached upon the State from the east toward the west. To be more exact, it was probably from the northeast, because the greatest thickness of Upper Cambrian strata is in Clinton county along the northeastern side of the Adirondacks.

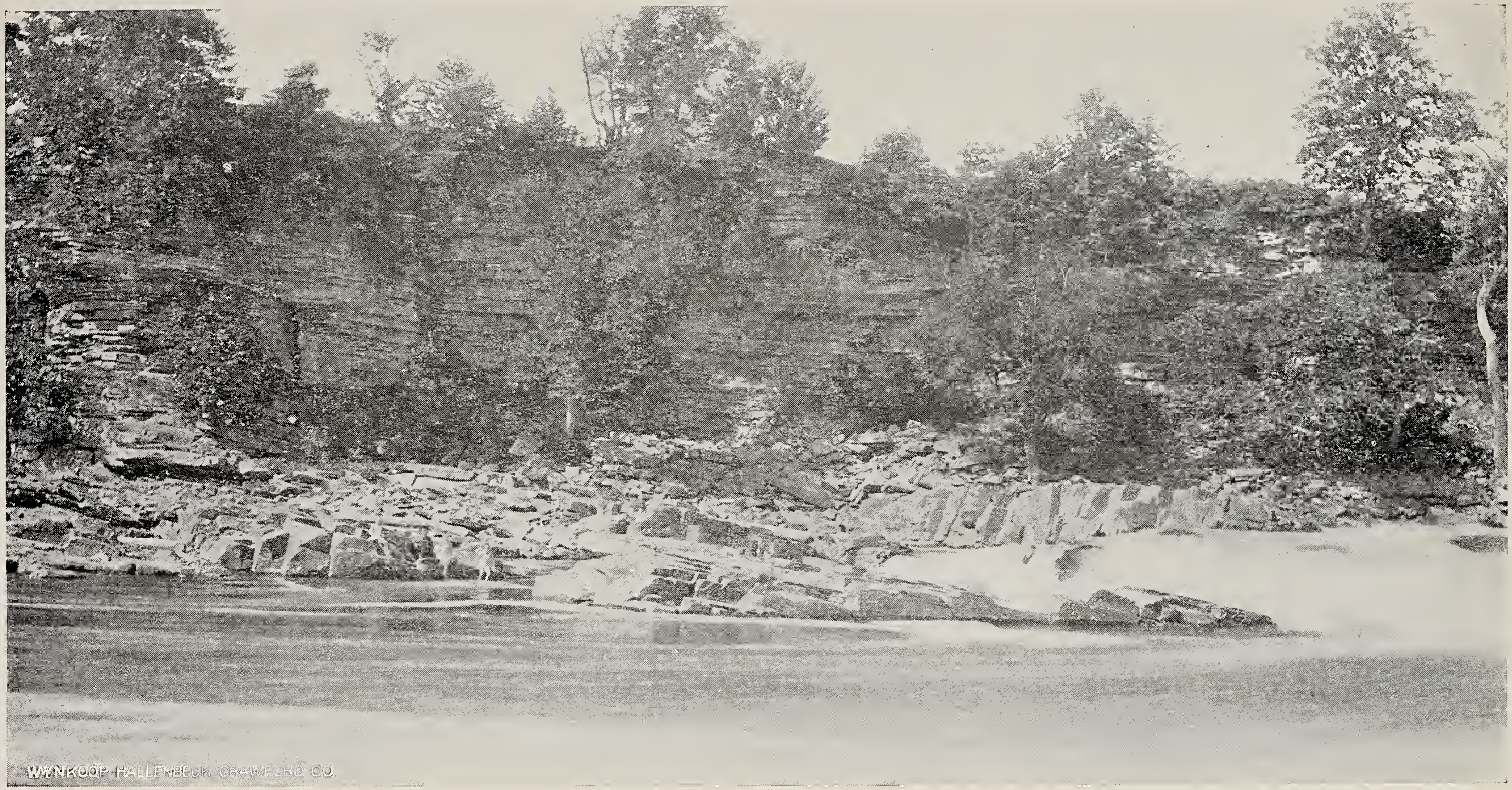
The first deposit to form in the Cambrian sea of northern New York was the Potsdam sandstone and the presence of this formation in the St Lawrence, Champlain, and lower Mohawk valleys proves that the Potsdam sea occupied all these regions. Along the



The Grand Flume of Ausable chasm, Clinton county. The rock is Potsdam sandstone in horizontal layers, and the gorge is postglacial.

From N. Y. State Mus. Bul. 19, pl. 22

Plate 19



Potsdam (Upper Cambrian) sandstone resting upon the eroded surface of Precambrian rock (gneiss) at Corinth, Saratoga county. The difference in age of the two rock masses here in contact is millions of years.

From N. Y. State Mus. Bul. 19, pl. 20

southwestern border of the Adirondacks the Potsdam is absent and there is not the slightest evidence that it ever was present there, so that region must have been dry land in Potsdam time. In the southeastern Adirondacks the Potsdam sea certainly extended in as far as Wells (southern Hamilton county) and North River (northwestern Warren county), because small outlying masses of Potsdam sandstone occur at those places. These outlying masses were formerly connected with the larger areas, but they have become completely separated from them by extensive (Postpaleozoic) erosion and downfaulting. There is no evidence whatever that the sea covered the heart of the Adirondacks. *To summarize for northern New York, we may say that the Potsdam (Upper Cambrian) sea covered the whole region except the central and southwestern Adirondacks which stood out as a great island in the midst of that ocean.* Southeastern New York certainly, and the middle eastern border of the State probably, were covered by the Upper Cambrian sea, but whether that sea extended over the rest of the State has not been determined because all early Paleozoic strata, if present, are there now deeply buried.

What do we know about the character of the topography of the land over which that ancient Potsdam sea spread? As a result of the very long erosion during late Precambrian and early Paleozoian time, thousands of feet of material had been removed so that rocks which had been so deeply buried were exposed at the surface, and the whole country must have been well worn down. Was the region worn down to the condition of a peneplain? Recent detailed studies on all sides of the Adirondacks furnish a very satisfactory answer to this question. In many places the Potsdam has been seen in actual contact with the Precambrian rock whose surface oftentimes clearly proves that the whole region had reached a peneplain condition. Along the northeastern Adirondacks this peneplain was considerably rougher than along the northwestern and southwestern portions. This is explained by the fact that the northeastern area subsided first and consequently was not subject to wear quite as long as the latter named areas.

The accompanying figure (no. 15) affords an interesting example of the kind of peneplain topography here considered. It demonstrates that occasional low knobs of more resistant rock (for example, Grenville quartzite) protruded above the otherwise nearly featureless plain, because when the Potsdam sea overspread the region such low knobs were not covered by the water. At this same locality there is a fine exhibition of coarse conglomerate at the base of the Potsdam sandstone, the boulders of the conglomerate often ranging from one to three feet across. These boulders were torn off the Adirondack cliffs by the waves of the Potsdam sea and were deposited near shore in local depressions of the old rock surface. The sandstone itself everywhere abounds in ripple marks, thus proving the shallow water (near shore) origin of the rock. All the rock in the walls of the famous Ausable Chasm (Clinton county) is Potsdam sandstone (plate 18).

Immediately overlying the Potsdam and showing about the same areal distribution, are alternating sandstones and limestone beds (Theresa formation) which show a thickness of from 50 to 200 feet. After still greater subsidence, the important formation known as the Little Falls dolomite (limestone) was deposited, layer upon layer, in the Upper Cambrian sea. This formation which is hard, compact and of light gray color, shows a thickness of several hundred feet in the gorge at Little Falls. It rests directly upon the Precambrian rock there (see figure 7), and this shows that the Cambrian sea spread over that region for the first time when that dolomite was forming. The Little Falls sea swept all around the Adirondacks, except what is now the western border from Trenton Falls to the Thousand islands district. Occurrence of the dolomite in small outlying masses at Wells (Hamilton county) and Schroon Lake (Essex county) proves that the Little Falls sea extended well into the eastern Adirondacks. Rocks of this age appear to be present in southeastern New York and if so, the Little Falls sea also overspread that region. Direct evidence for western and southern New York is wholly lacking, but judging by the occurrence in central Pennsylvania of rocks of the same age as the Little Falls

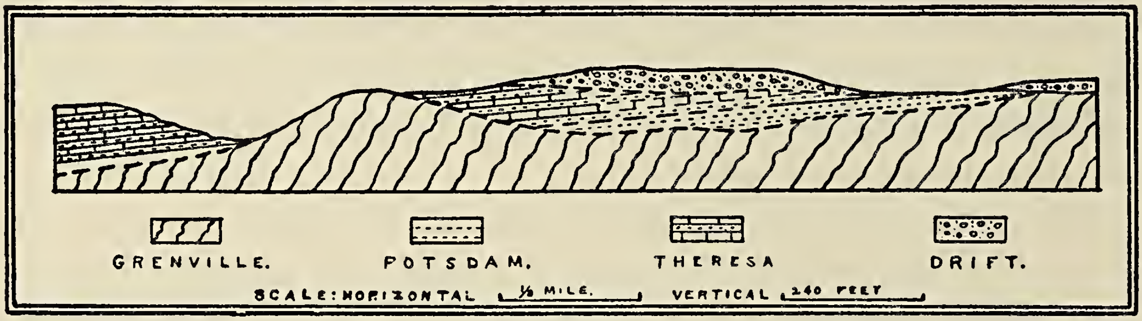
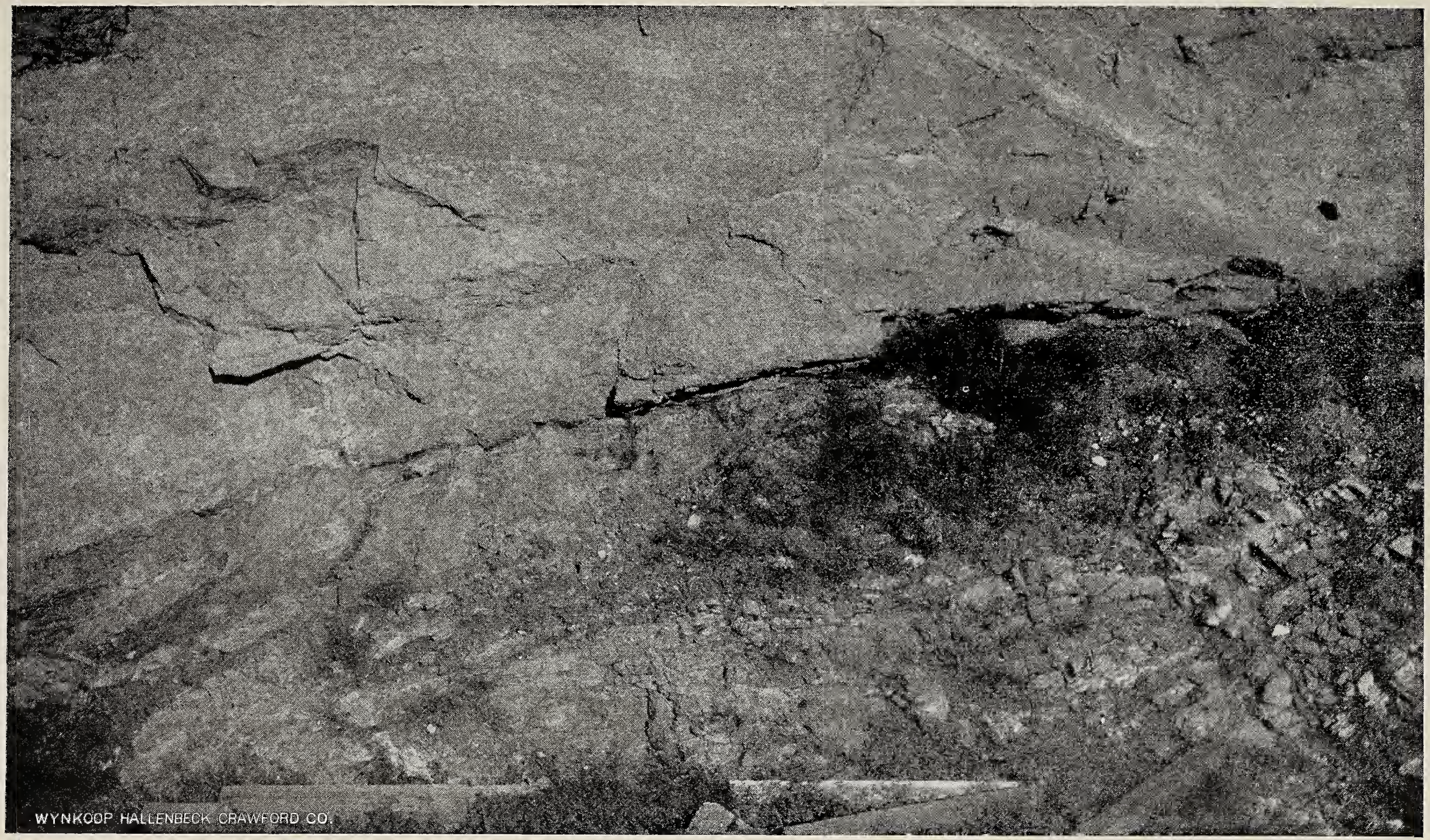


FIG. 15 Section passing through North Galway in Saratoga co. and showing how the Cambrian (Potsdam and Theresa) strata overlap upon a hillock of Precambrian rock. This knob of Precambrian rock stood above the general level of the peneplain (early Paleozoic) and was not submerged under the Potsdam sea.

After W. J. Miller, N. Y. State Mus. Bul. 153, p. 5

Plate 20



Little Falls (late Cambrian) dolomitic limestone resting upon the eroded surface of Precambrian rock as seen in a West Shore Railroad cut 1 mile west of Randall, Montgomery county.

From N. Y. State Mus. Bul. 19, pl. 25

dolomite, it is highly probable that the Little Falls sea also covered western and southern New York.

The Little Falls dolomite is especially significant in two ways; first, because it is the youngest (uppermost) Cambrian formation in the State, and second, there is a distinct unconformity at its summit. By unconformity here we mean that, after the deposition of the dolomite, at least all of northern New York was raised (without folding or faulting) above sea level and underwent erosion for a moderate length of time after which most of the region again settled below sea level to receive the deposits of later (Ordovician) age. This old eroded surface and unconformity has been well established, and hence we learn that *the great Cambrian period of the early Paleozoic era closed with all of northern New York, at least, well above sea level.* In southeastern New York, as far as known, the Cambrian strata appear to grade into the Ordovician and if so, that region was not raised above sea level at the close of the Cambrian. We are wholly ignorant as to the physical geography of western and southern New York at the close of the Cambrian because the records there are not accessible, that is they are deeply buried.

ORDOVICIAN PERIOD

We are now ready to consider the physical condition of the State during the great Ordovician period of earth history. During this time the Appalachian mountain region, the great Mississippi valley, and much of the far western region were almost continually under water (see figure 16). In fact, the very widespread distribution of thick Ordovician strata shows that more of North America was covered by the Ordovician sea than by any other sea, with the possible exception of the Precambrian. Among the more prominent lands which persisted above water were Appalachia, which was a great land mass occupying what is now the Atlantic sea board and extending an unknown distance into the Atlantic, and another large land area in the Hudson Bay region of Canada. Sediments from those lands were washed into the Ordovician sea which covered most of the State during the entire period. In eastern and southeastern New York, the almost unbroken succession of Ordovician strata shows that the sea was much of the time present there during the entire period. The prominent development of Ordovician strata west and south of New York makes it practically certain that the western and southern portions of the State were submerged under the Ordovician sea. In northern New York, however, there is no positive evidence that the whole Adirondack area was ever completely submerged during this period. Accordingly the central Adirondacks formed a persistent island in the Ordovician sea. Furthermore, in northern New York there were various rather local oscillations of level bringing the land around the island now above and now below sea level, but all such details are here omitted. For our purpose it will suffice to say that, except for the Adirondack island, northern New York was mostly below sea level during the Ordovician. To summarize the above statement: *New York State was completely submerged under the Ordovician sea except for an Adirondack island and alternating land and water conditions immediately around that island.*

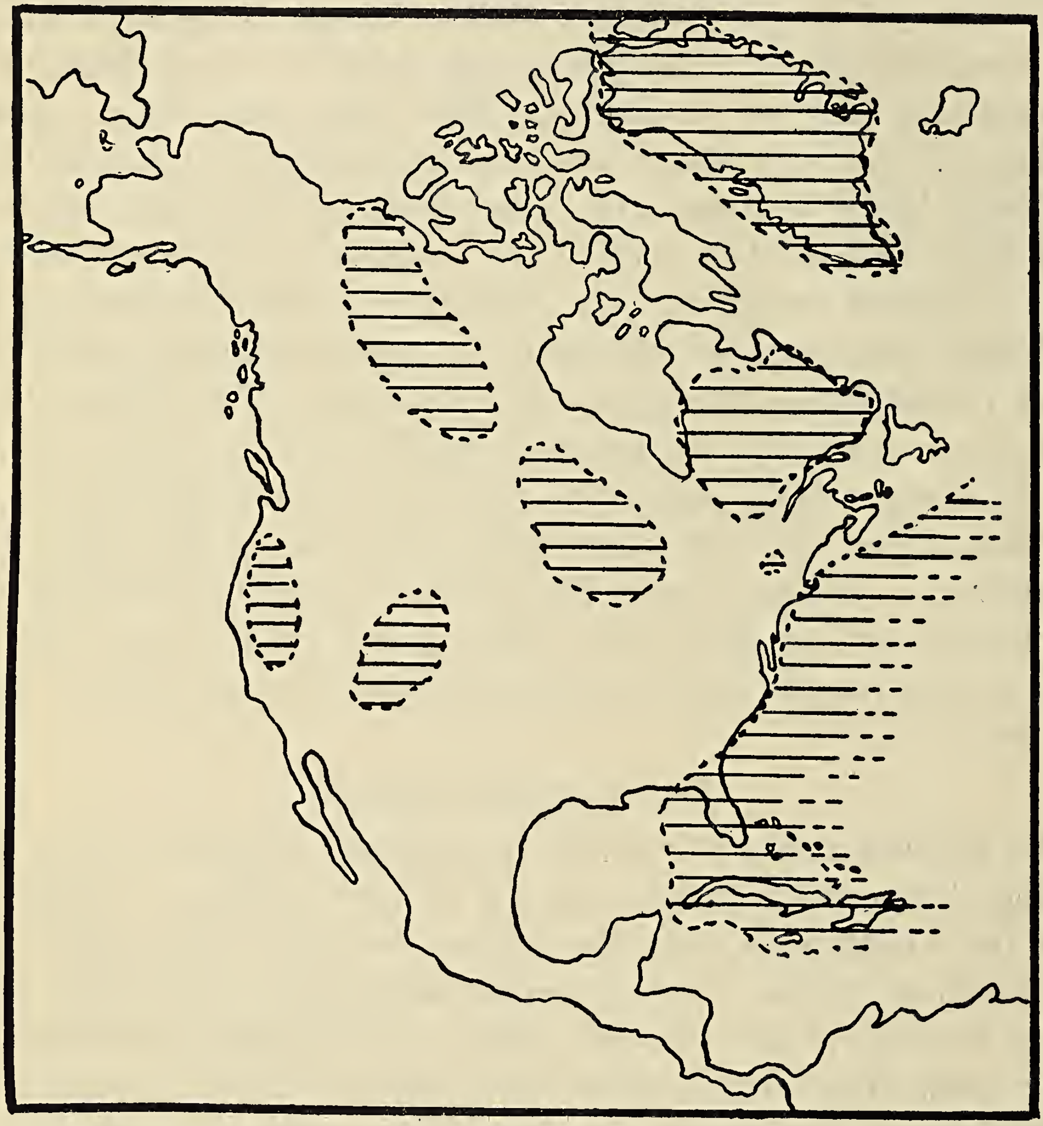
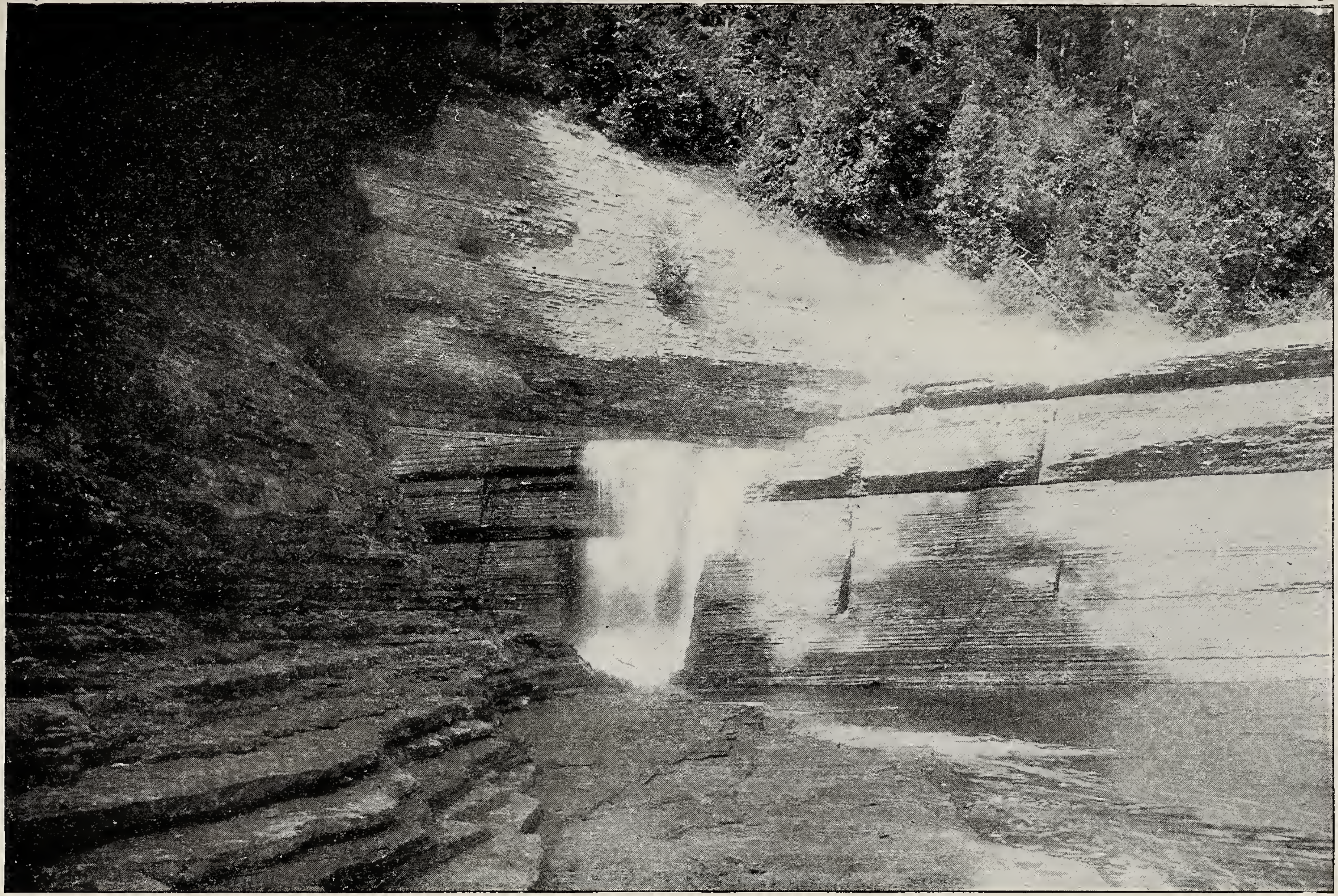


Fig. 16 Generalized map of North America showing the relations of land and water during the Mid-ordovician period. Horizontally lined areas = land; blank areas = water. All of New York State was submerged except the central Adirondacks which stood out as an island. The conditions in Mexico and Central America are practically unknown.

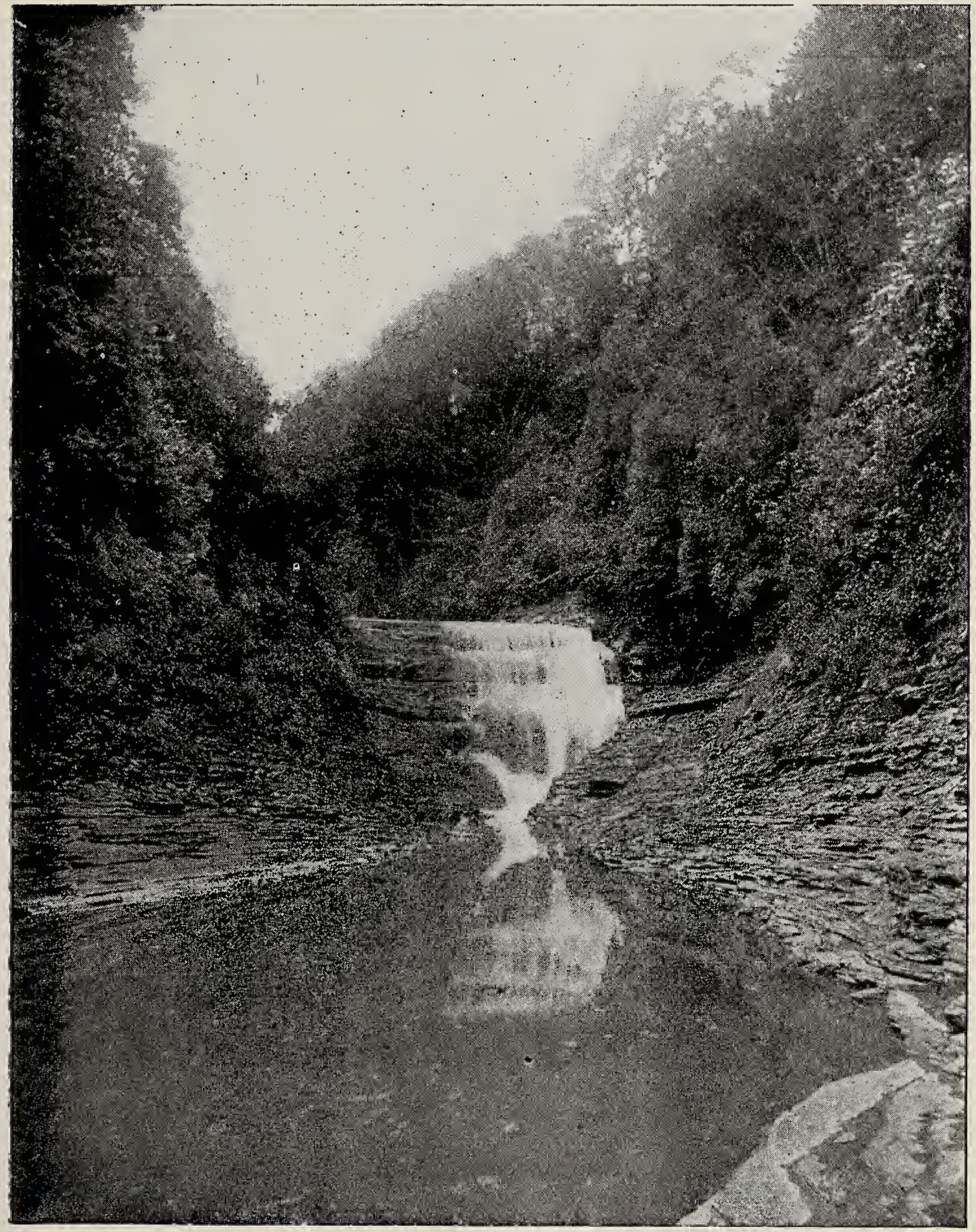
Plate 21



Trenton (Ordovician) limestone at Sherman fall in the gorge at Trenton Falls, Oneida county. The thin-bedded and perfectly stratified character of this impure limestone is here well shown. This famous formation, loaded with fossils, was named from this locality.

From N. Y. State Mus. Bul. 95, pl. 9

Plate 22



Falls over Canajoharie (Trenton) black shale south of Canajoharie, Montgomery county.

From N. Y. State Mus. Bul. 19, pl. 35

Without going into the details of the formations, it is important to note that the earlier Ordovician deposits were almost wholly limestones, while the later deposits were nearly all shales and sandstones. Thus in southeastern New York the thick Wappinger limestone is overlain by the still thicker Hudson River shales and sandstones. In northern New York we have the Beekmantown, Chazy, Black River, and Trenton limestones overlain by the Trenton (Canajoharie), Utica, and Frankfort shales and sandstones. It should not be understood, however, that all the formations named are present in unbroken succession, because the oscillations of level (above mentioned) occasioned certain interruptions in sedimentation.

The predominance of limestone deposition in the earlier Ordovician sea of New York proves that the waters of that time were comparatively free from land-derived sediments and this, in turn, is best accounted for not by great depth of water and distance from land, but rather by the fact that all the nearest land areas were comparatively low and small, and hence were not undergoing very active erosion. During the later Ordovician the adjacent lands were considerably higher and no doubt larger, so that vigorous erosion resulted and muds and sands were largely washed into the sea.

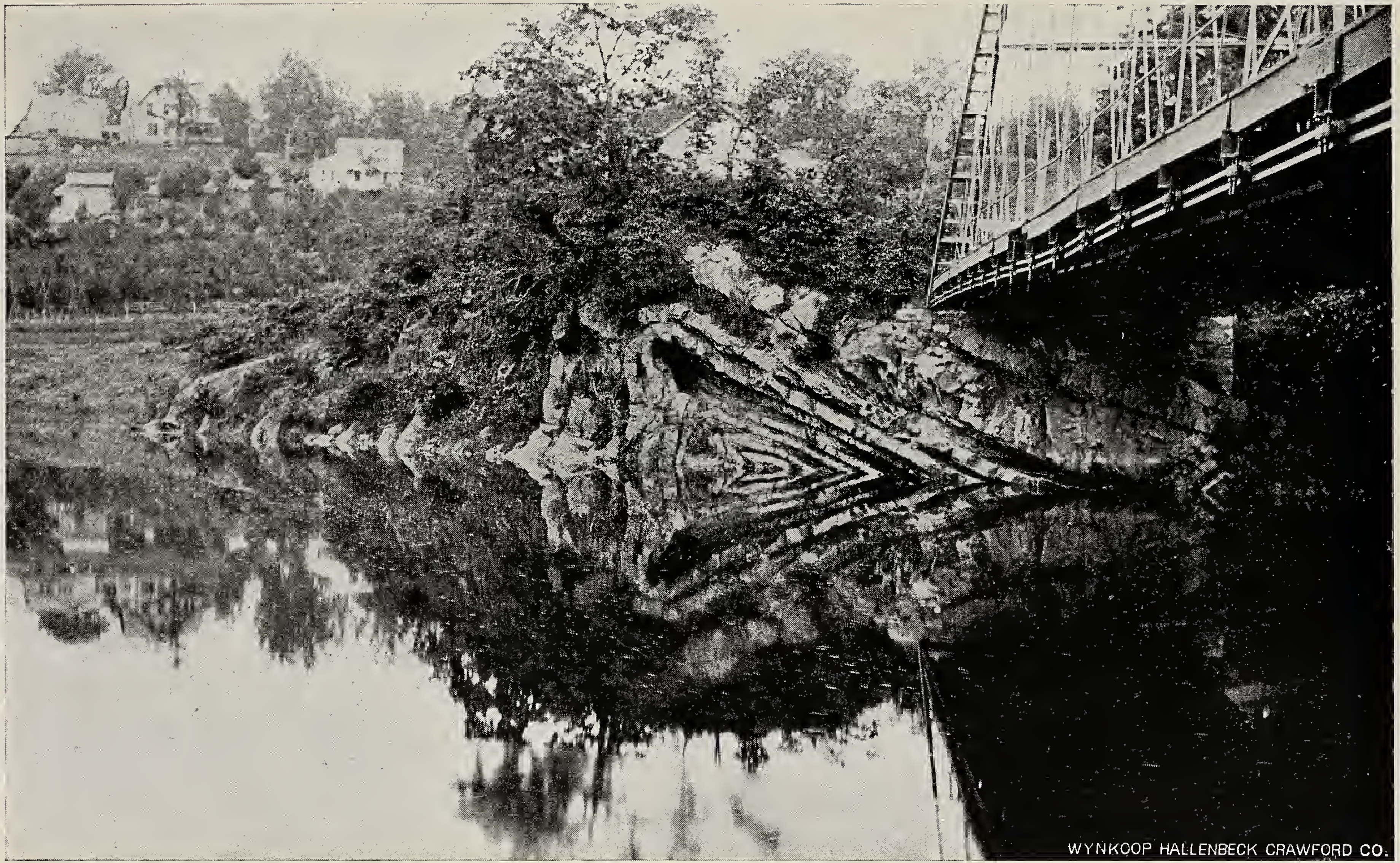
The aggregate thickness of Ordovician strata in New York is between 2000 and 3000 feet. It should not be inferred from this fact that the Ordovician sea was ever two or three thousand feet deep. Even the limestones abundantly show by ripple marks, mud cracks, fossils etc. that they were laid down in shallow sea water. The very character of the materials (old muds and sands) in the Upper Ordovician formations shows that they could not have been deposited in deep ocean water. Such sediments are not now forming on the deep sea bottom. But how are these statements to be harmonized with the fact that nearly 3000 feet of Ordovician strata exist in New York? During the whole period (with certain exceptions above noted) the land gradually subsided, and during this slow downward movement stratum after stratum was formed upon the sinking sea-floor, so that for no part of the time is it necessary to assume great depth of water. In general, the Ordovician sea of North America must be thought of as a vast, shallow (continental) sea which spread over most of the slowly subsiding continent. There were no ocean abysses at all comparable to those of the present ocean.

In the strata of Cambrian age in New York, animal or plant remains are comparatively rare, while the Ordovician rocks throughout fairly teem with fossils. If any single formation deserves special mention, it is the Trenton limestone which is exceedingly rich in fossils. The type locality, at Trenton Falls, is justly famous as a collecting place for Ordovician fossils. Among plants, none above very simple seaweeds or algae are known to have existed. Among animals, hundreds of species have been described as occurring in the Ordovician strata of New York. These species represent all the more important subkingdoms and classes of animals below the vertebrate. Especially prominent are: corals, graptolites, star-fishes, brachiopods, gastropods and trilobites. All the organisims mentioned lived in the salt water, and if land life forms existed we know practically nothing about them. It must be borne in mind that not a single species of that time is known to live today, so complete have been the evolutionary changes since the Ordovician age. Certain remarkable classes of animals like the graptolites and trilobites, which often fairly swarmed in the Ordovician sea, have been wholly extinct for millions of years.

TACONIC MOUNTAIN REVOLUTION (CLOSE OF THE ORDOVICIAN)

We are now ready to discuss the second well-known mountain-making epoch which affected New York State. We have learned that sedimentation along the middle eastern border and southeastern parts of the State was practically uninterrupted during all the Cambrian and Ordovician periods, and that some thousands of feet of strata had accumulated. At the same time extensive sedimentation was taking place in the seas which covered all the regions of the present Berkshire hills, and Green mountains, as well as some distance southward. *At or toward the close of the Ordovician period a compressive force in the earth's crust was brought to bear upon the mass of sediments which extended through western New England and southeastern New York. As a result of this compression the strata were tilted, folded, and elevated above sea level into a mountain range known as the Taconic mountains.* In structure, the range consisted of a series of rock folds, whose axes were parallel to the main axis of the range, that is north-northeast by south-southwest. Examination of figures 14 and 20 will give the reader a good conception of the character of the folding. It is quite the rule throughout this region of Taconic disturbance to find

Plate 23



A small fold in the Hudson river (Ordovician) shales and sandstones along the lower part of Catskill creek in Greene county. This fold was produced at the time of the Taconic revolution.

From N. Y. State Mus. Bul. 19, p. 36

the strata either on edge or making high angles with the plane of the horizon. Although we have no way of telling just how high the range may have been, nevertheless the structural features, and the vast amount of erosion since the folds were produced, clearly indicate that the uplift was at least several thousand feet. The Green mountains, Berkshire hills, and Highlands-of-the-Hudson, the Piedmont plateau are, in a sense, remnants of the great Taconic range.

In passing westward from the main axis of the Taconic range, the folding becomes less and less intense, and finally dies out altogether. This fact is well illustrated by figures 6, 8 and 9. Along the Hudson river near Albany, the strata are fairly well folded, while a few miles westward the folds disappear. Passing eastward from Albany into Rensselaer county, one enters a region of excessive folding. In passing westward from Poughkeepsie, the intensity of the folding diminishes somewhat, but the shale formation is distinctly folded where it passes under the main mass of the Catskill mountains. Figure 6 clearly illustrates this fact.

How do we know that the Taconic disturbance occurred toward the close of the Ordovician period? Another inspection of figure 6 will show that the strata of the next succeeding period (Silurian) rest directly upon the eroded edges of the folds of late Ordovician rocks (see plate 25). Hence it is obvious that the disturbance occurred before the Silurian strata were deposited. What was the condition of the rest of the State just after the Taconic disturbance? In central New York, near Utica, a distinct eroded surface at the summit of the Ordovician shales proves that region to have been dry land toward the end of the period. On the north side of the Adirondacks and in the Champlain valley no formation younger than Ordovician shale occurs, and all evidence points to uplift of that area into dry land toward the close of the period. Data are not obtainable for western New York. To summarize: *Practically all of northern-central, eastern, and southeastern New York (including the great Taconic mountains) was dry land toward the close of the Ordovician period, while the physical geography of western New York for that time is not certainly known.*

It should be noted in passing that the rocks of the Highlands-of-the-Hudson were, for a second time, clearly involved in mountain-making disturbances. The structural features of the Taconic mountains are finely exhibited in southeastern New York from Poughkeepsie to New York City, where one literally passes across the roots of the former great range. The distinct northeast-southwest trend of the topographic relief in this part of the State is due to the fact that the relief is still largely controlled by the Taconic folds and faults. The Hudson river has cut a deep channel across these structure lines, and along its banks excellent opportunity is afforded for the study of the rocks, folds, faults etc.

Another feature which must not be overlooked is the profound metamorphism of the strata along the main axis of the range. The very intense compression, under very high moist heat, caused the deeply buried strata along the main axis of uplift to become rather plastic, and hence the sediments became more or less foliated and crystallized into the various metamorphic rock types, the limestone becoming marble, the shale becoming slate or schist, and the sandstone becoming quartzite. Thus we have extensive marble quarries in southern Vermont, the slate in the quarries of Washington county, New York, and the Berkshire schist in the Berkshire hills of Massachusetts. In passing down the Hudson river from Kingston to New York City, the several stages in the metamorphism of the Ordovician slate formation are finely illustrated. Thus, from Kingston to near Poughkeepsie the strata are distinctly folded but not metamorphosed; from Poughkeepsie to the Highlands, the strata are highly folded and partially metamorphosed, the shale layers nearly always having been changed to slate, while the associated and more resistant sandstone layers have escaped change; from the Highlands to New York City the rocks have been highly folded and metamorphosed, both shale and sandstone having been converted into schist locally called the Manhattan schist. For example, the rocks exposed in Central Park are Manhattan schists which are believed to have been originally Hudson River shales and standstones which have become thoroughly crystallized by intense metamorphism.[1]

The great force which folded and upraised the Taconic mountains did not accomplish its work suddenly. The force was slowly and irresistibly applied and the mass of strata was gradually bulged and bent, or fractured if near the surface, the amount of time required for the whole operation being perhaps very long but beyond estimate. Such a length of time is, however, so short compared with

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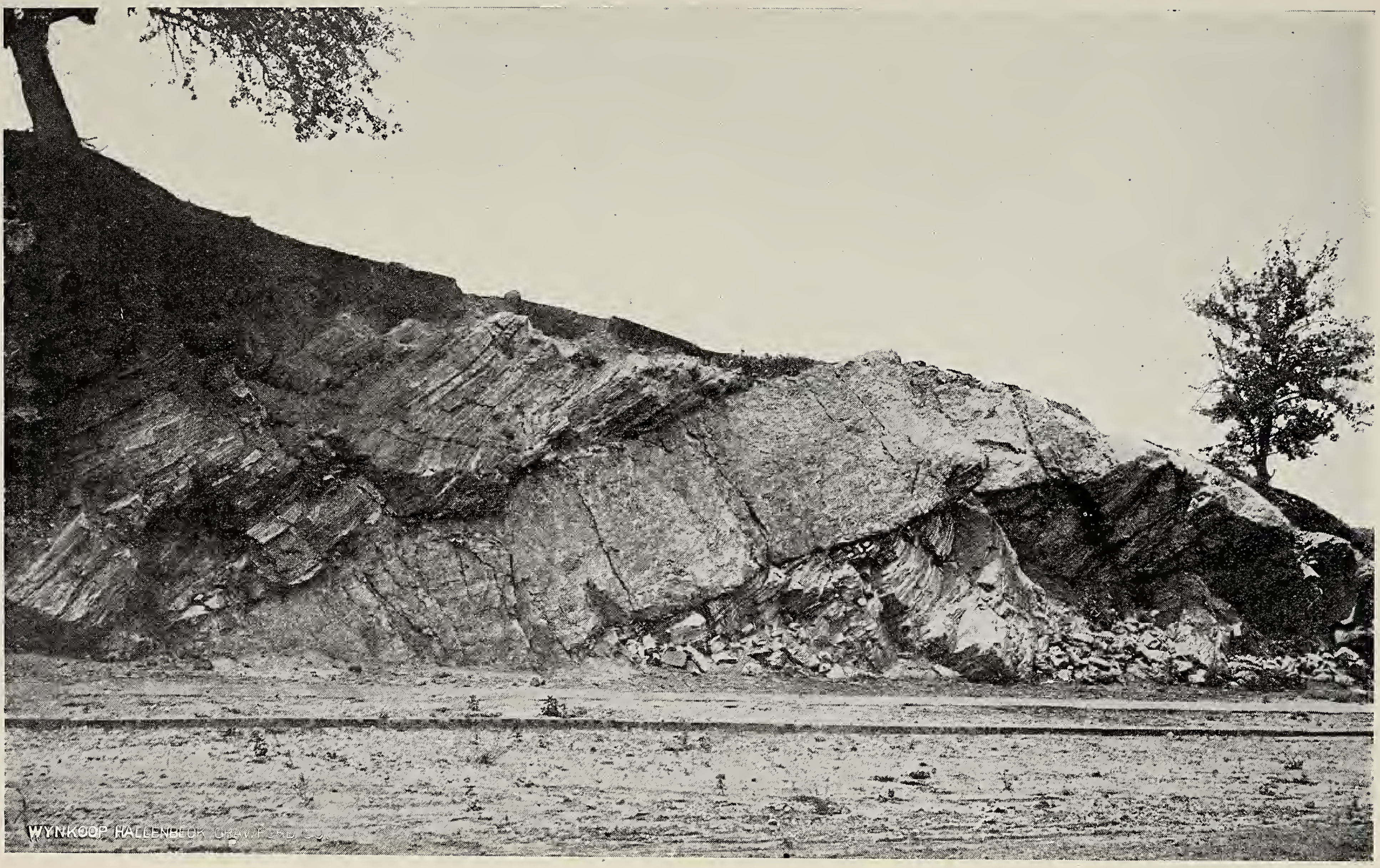
[1] Professor Berkey has suggested that the Manhattan schist may be Precambrian in age; if so, the latter part of this statement does not apply. It should also be stated that, to some extent at least, the rocks of southeastern New York were also affected by folding (and possibly metamorphism) at the time of the Appalachian Revolution, described beyond.

Plate 24



Granite dike in Manhattan schist, as seen on the south side of 192d street, New York City. The schist is metamorphosed shale and sandstone, and the granite, while molten, broke its way through.

From N. Y. State Mus. Bul. 19, pl. 1

all known geologic history that we are accustomed to refer to the formation of such a mountain range as simply an event of earth history.

From these statements we see that, even before the range had attained its maximum height above sea level, a very considerable amount of erosion must have taken place. When the very first fold appeared above the ocean level, erosion began its work and continued with increasing vigor as the mountain masses got higher and higher. Thus we have the example of the warfare between two great natural processes — the building up and the tearing down. As long as the building up process predominates, the mountain range increases in elevation, and we say the range is in its period of youth. When the opposing forces are about equally balanced, the range tends to remain at a constant elevation and we say the mountains were in the period of maturity. When the tearing down (erosive) process is predominant, we speak of the range as being in old age. When the mountains are worn down almost to sea level (peneplain) we speak of the death of the range.

Here is an example of one of the remarkable procedures of nature. After millions of years of work by the deposition of thousands of feet of strata, layer upon layer on an ocean bottom, a compressive force is brought to bear and a magnificent mountain range is literally born out of the ocean. No sooner is this great mountain range well formed than the destructive processes unceasingly destroy this marvelous work. But the sediments derived from the wear of this range are carried into the nearest ocean again to accumulate and, after long ages, to be raised up into another range; and so the process is often repeated. From this we learn that the mountain ranges of the earth are by no means all of the same age. The Adirondacks are older than the Taconics, and these latter are older than the Appalachians; and the Appalachians being older than the Sierras and the Coast ranges. Much of the material making up the mass of the Catskill mountains was derived from the wear of the Taconic mountains, deposited in the sea just to their west and later raised high above sea level.

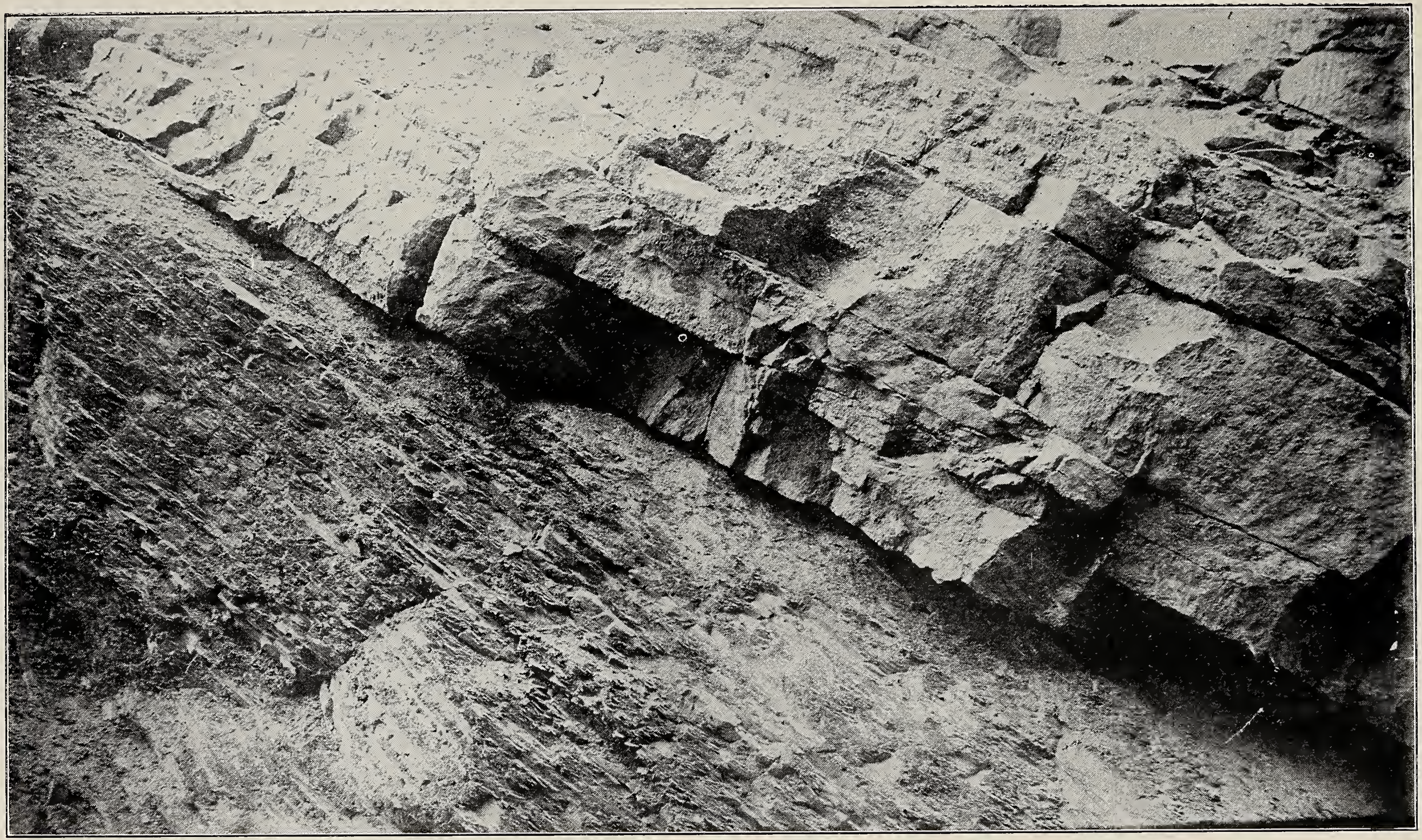
SILURIAN PERIOD

The close of the Ordovician age or the opening of the Silurian found practically all the State above sea level and undergoing erosion. Along the eastern side the Taconic range stood out prominently, but over the rest of the State we have no evidence that the land was very high. The central portion of the Adirondack region probably stood out somewhat more prominently than the western region.

As shown on the geologic map (figure 1), the Silurian strata outcrops in a comparatively narrow belt which runs along the western side of the Hudson valley to the Helderberg hills, southwest of Albany, where it swings sharply around westward to follow the south side of the Mohawk valley, and thence as a somewhat wider belt along the south side of Lake Ontario. These Silurian strata everywhere dip under the Devonian (surface) rocks of the Catskill and Southwestern plateau provinces. This fact, combined with the knowledge that the strata are largely of widespread marine origin and also that they outcrop abundantly in central Pennsylvania, make it practically certain that the Silurian rocks underlie all of the Catskill and southwestern plateau regions. *Thus we must conclude that during at least much of Silurian time all of New York State south of Lake Ontario and the Mohawk valley, and west of the Hudson river, was covered by sea water.* That the earliest Silurian sea did not spread over the area is proved by the absence of the very earliest known Silurian deposits. Furthermore, we know that the sea transgressed upon the State from the south or west, because the Taconic range formed an effective barrier on the east and total absence of Silurian strata in the St Lawrence and Champlain valleys (as well as in Canada just north of the State) precluded the possibility of encroachment of the sea from the north.

This encroachment of the sea over so much of the State was due to a gradual sinking of the land. That central and western New York was submerged earlier than the Hudson valley region is proved as follows: In central New York (south of Utica) the first deposit to form upon the eroded surface of the Ordovician shales was the Oneida conglomerate which passes westward into the Medina sandstone. In southeastern New York (for example, the Shawangunk mountain) the first Silurian deposit to be laid down upon the eroded Ordovician shales was the Shawangunk conglomerate. This latter formation, as determined by its fossils, belongs with the Salina division and is therefore much younger than the Oneida conglomerate which belongs with the Medina division (see table in chapter 1). Also the whole of the Clinton and Niagara formations, which are so well developed in central and western New York, were never formed in eastern or southeastern New York. Thus the Silurian sea, due to subsidence of the land, overspread

Plate 25



Shawangunk (Silurian) conglomerate resting upon the eroded edges of Hudson River (Ordovician) shales, thus showing a sharp contact between rocks of two great periods of earth history. The shale layers are more steeply inclined because they were affected by both the Taconic and Appalachian disturbances, while the conglomerate was affected only by the latter disturbance.

From N. Y. State Mus. Rep't 60 (2), 1906, pl. A, facing p. 298

central and western New York long before it reached the Hudson valley region. In fact it was not until late in the period that the sea encroached upon the Hudson valley area, and then it did not occupy all of that area because the shore of the Silurian sea extended only as far east as the western slope of the Taconics. Western New York, during the late Silurian, was a more or less cut off basin or arm of the sea in which the salt beds were being deposited.

How much, if any, of the Adirondack region was covered by the Silurian sea? The total absence of any formation later than the Ordovician shales around the northern Adirondacks and across the line in Canada strongly suggests that this region was upraised toward the close of the Ordovician period, perhaps at the same time as the Taconic revolution, and that it continued as dry land not only during the Silurian but also during all the ages up to the present, except for a very brief local submergence during the Quaternary (see figure 34). In the southern Adirondack area the case is somewhat different. The outcrops of Silurian strata beneath the steep front of the Devonian Helderberg escarpment immediately south of the Adirondacks, makes it certain that these strata, and therefore the Silurian sea formerly extended farther north. The difficulty comes in trying to decide how far northward these rocks once extended, because there is now not a single scrap of Silurian rocks north of the Mohawk river, though the cap rock (Oswego sandstone) of the Tug Hill plateau is probably of Silurian age. All we can say is that the Silurian sea probably overspread the southern border of the Adirondacks and that the sediments which were deposited there have since been removed by erosion. To summarize: *During the early Silurian the sea had spread over only central and western New York, while during the late Silurian it had extended over practically all the State west and south of the Adirondack region.*

The strata of Silurian age were deposited sheet upon sheet in the usual manner upon the sea bottom. For our purpose we may consider that sedimentation was uninterrupted, though as a matter of fact there were certain minor oscillations of level which interfered with the deposition of sediments, and which produced slight unconformities. These minor interruptions have not yet been studied carefully, and hence they need not be considered here. The total thickness of Silurian strata along the line of outcrop in the

State varies considerably. In central and western New York the thickness is generally from 1000 to 1500 feet, while in southeastern New York it is much less since only the thinned upper formations are present.

The first Silurian sediments to form in central and western New York are called the Oneida conglomerate and Medina sandstone,

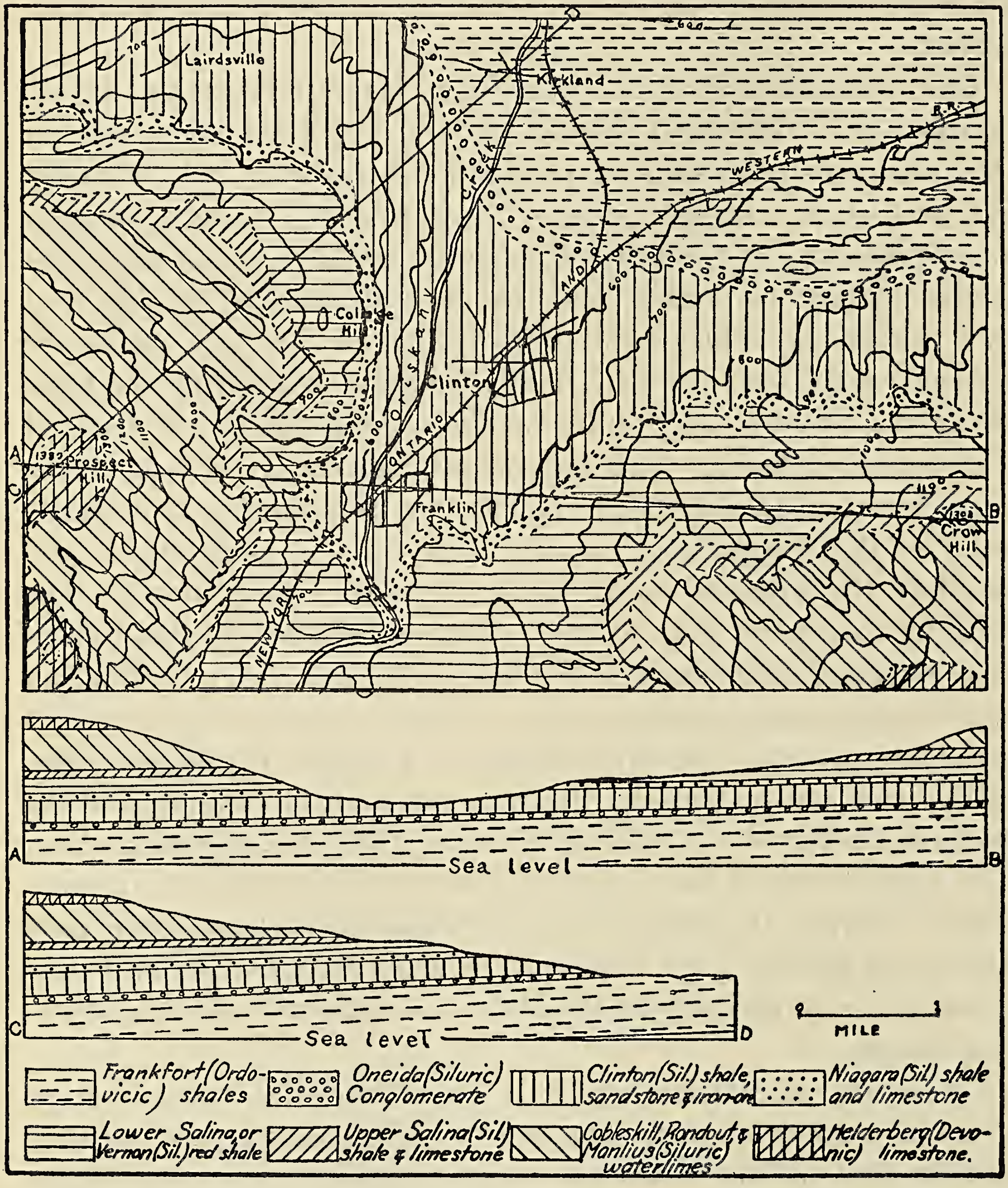
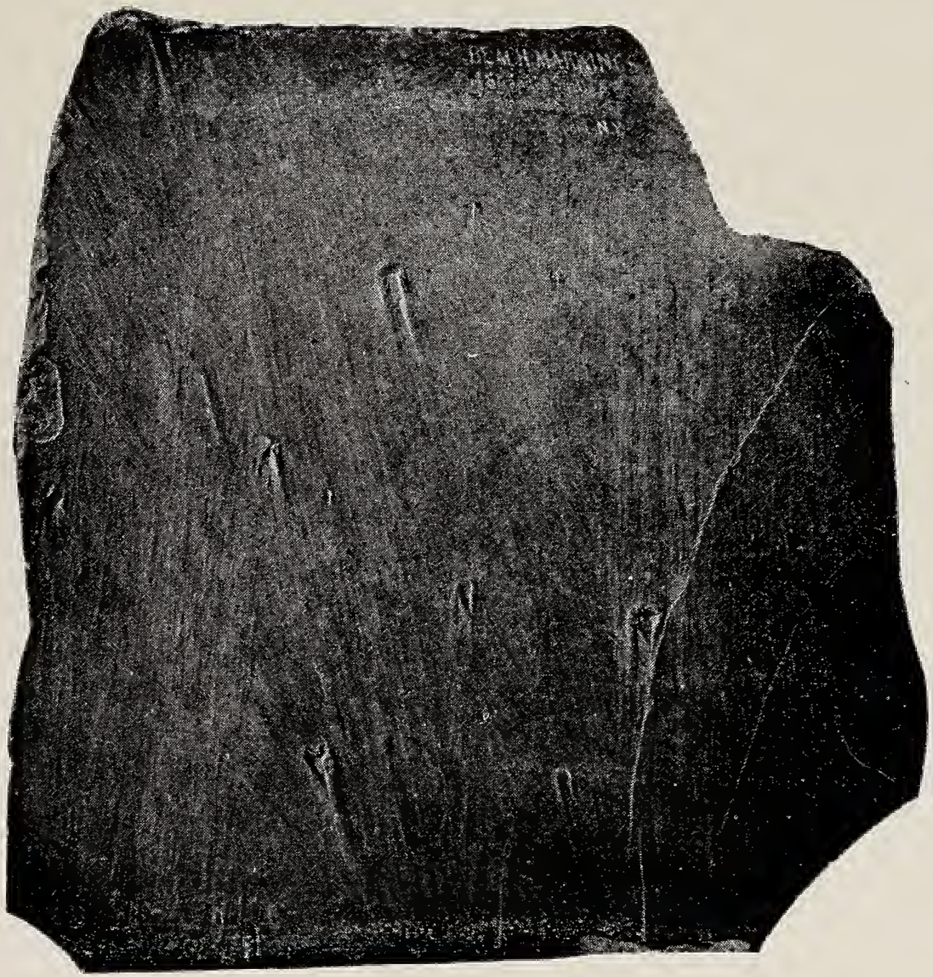

Lairdsville
Kirkland
Prospect Hill
1382
College Hill
Clinton
Franklin
Crow Hill
1382
Oriskany Creek
New York Ontario and Western R.R.
A
B
C
D
600
700
800
900
1000
1100
1190
Sea level
Sea level
1 MILE
Frankfort (Ordovicic) shales
Oneida (Siluric) Conglomerate
Clinton (Sil.) shale, sandstone & iron-ore
Niagara (Sil.) shale and limestone
Lower Salina, or Vernon (Sil.) red shale
Upper Salina (Sil.) shale & limestone
Cobleskill, Rondout & Manlius (Siluric) waterlimes
Helderberg (Devonic) limestone.

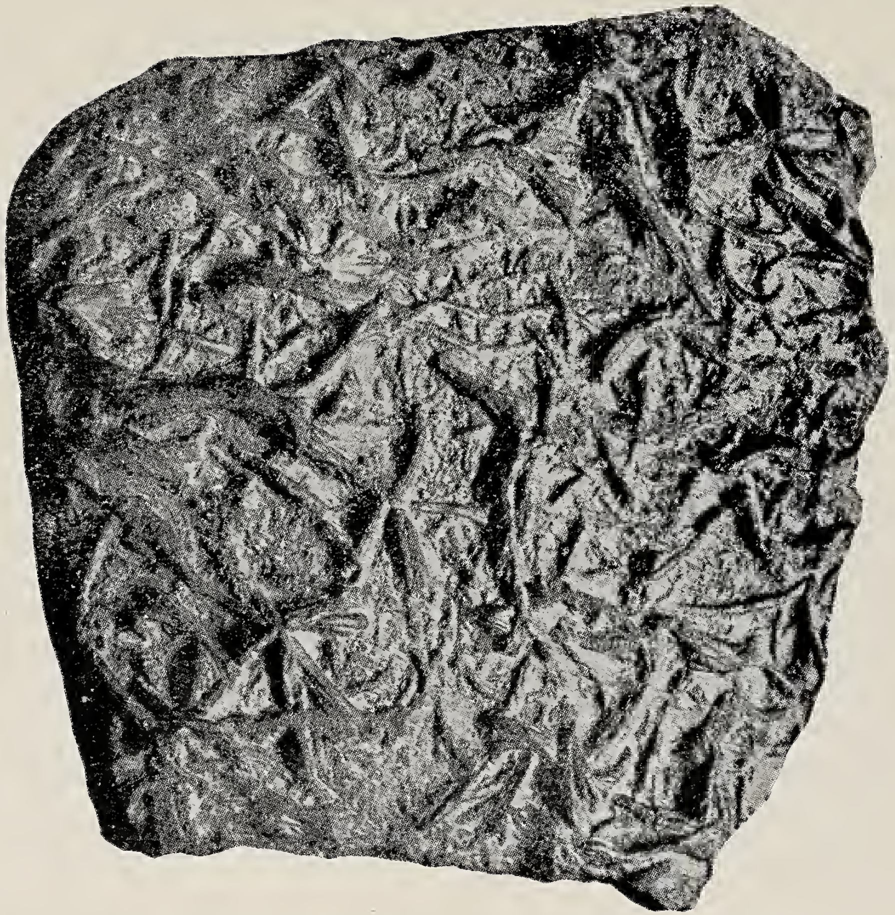
FIG. 17 Geologic and topographic map and structure sections of the vicinity of Clinton (Oneida county) showing the surface distribution and underground relations of the various rock formations from the Upper Ordovician to the Lower Devonian inclusive. Note the simple nonfolded and nonfaulted structure, and the gentle southwesterly dip (tilt) of the formations. A similar simple structure characterizes the formations of the whole southwestern plateau province. Vertical scale of the sections four times exaggerated.

Geology by W. J. Miller

Plate 26

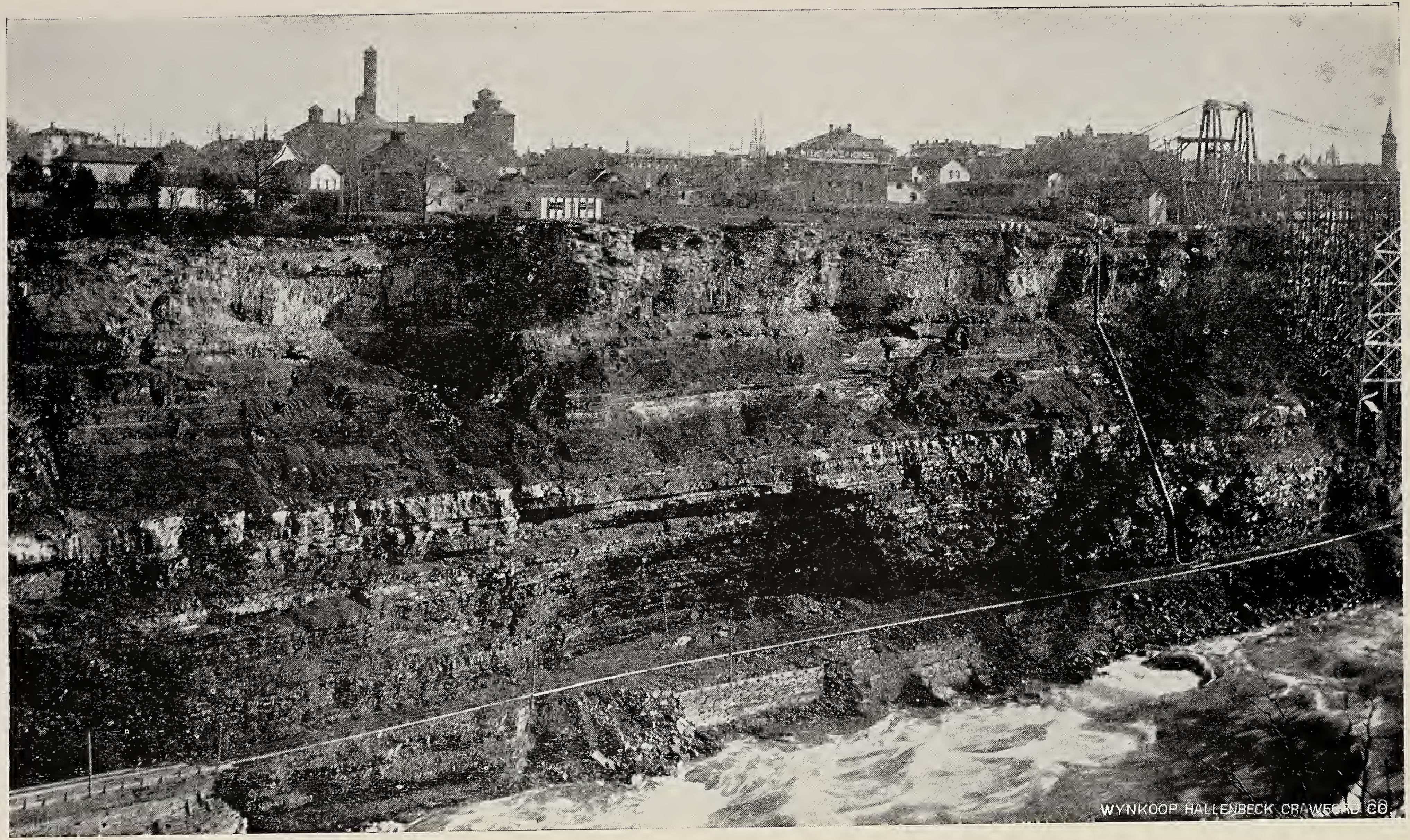


Beach markings on Medina sandstone



Seaweed, Arthrophycus harlani, on Medina sandstone
From N. Y. State Mus. Bul. 19, 45

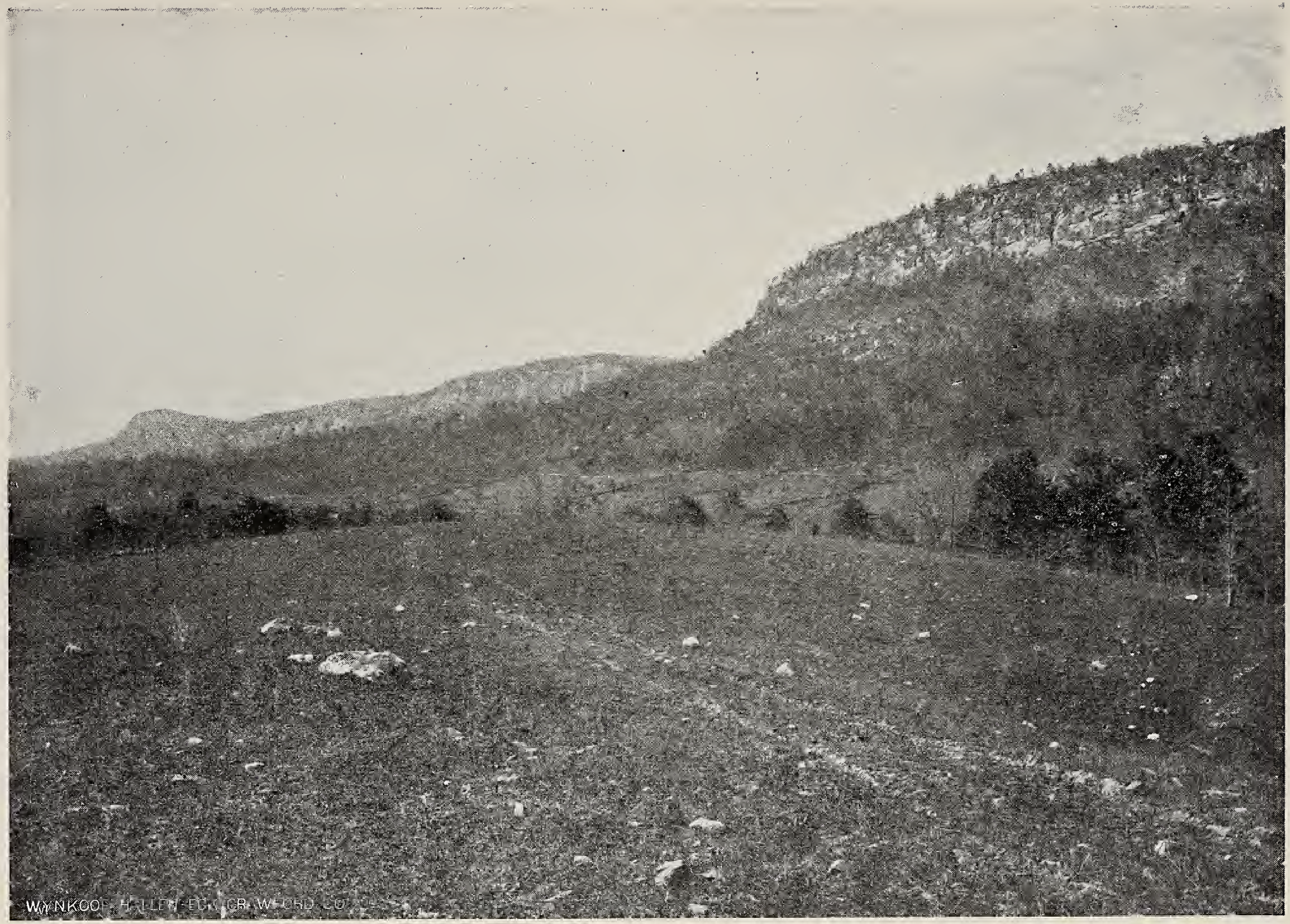
Plate 27



Niagara river gorge below the Suspension bridge, as viewed from the Canadian side. Very distinctly stratified beds of Lower Silurian (Medina, Clinton and Niagara) age are shown.

From N. Y. State Mus. Bul. 19, pl. 55

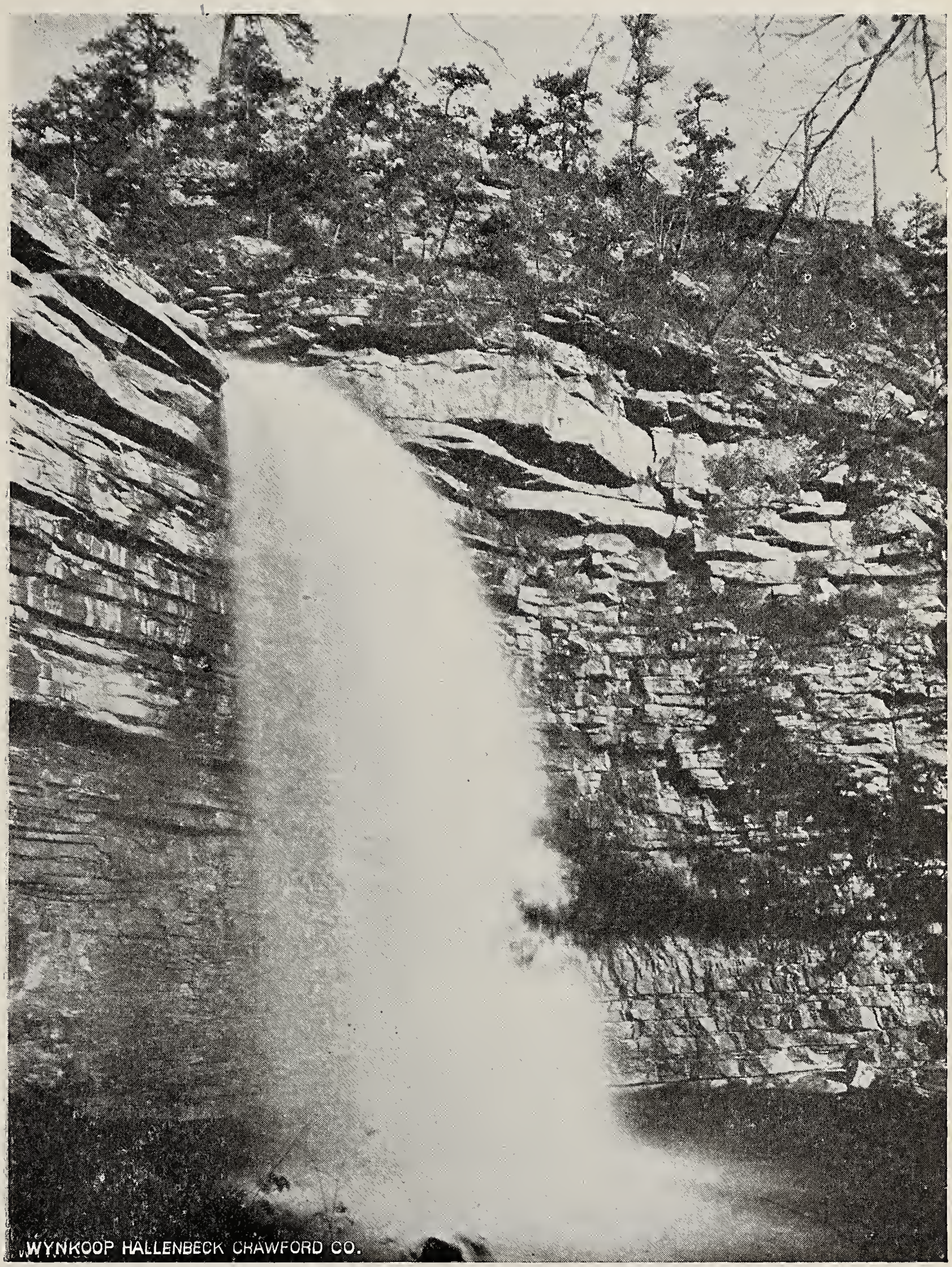
Plate 28



The eastern face of Shawangunk mountain, 2 miles south of Lake Mohonk, Ulster county. The light-colored rock forming the summit of the ridge is the very resistant Shawangunk conglomerate which protects the soft underlying mass of Hudson River (Ordovician) shales.

From N. Y. State Mus. Bul. 19, pl. 40

Plate 29



Awosting falls over Shawangunk conglomerate, Peterkill, near Lake Minnewaska, Ulster county

From N. Y. State Mus. Bul. 19, pl. 42

these two being of practically the same age. These coarse deposits were washed into the shallow sea from the northern lands, that is from Canada and the Adirondack region. Next in order came the deposits of Clinton age, which consist of layers of shale, sandstone, and iron ore. Above the Clinton come the Lockport and Guelph formations which are made up of shales and dolomitic limestone, the limestone forming the crest of Niagara Falls. None of the formations, so far mentioned, extend to the Hudson valley, but with the opening of the great Salina epoch Silurian deposits for the first time reached to the Hudson valley region where the earliest rock to form was the Shawangunk conglomerate which rests upon the eroded Ordovician shales at the summit of Shawangunk mountain. This rock is entirely confined to southeastern New York, while rocks of the same age in central and western New York are shales and limestones. In this latter region the lowermost (oldest) Salina formation is the Vernon red shale, usually from 100 to 300 feet thick, and which, in the western part of the State, is overlain by the salt and gypsum beds. Deep wells have proved the presence of the salt beds under practically all the Southwestern plateau. The salt was deposited in great salt lagoons and the climate of the time must have been arid. With an influx of fresh water into the lagoons, the type of deposit changed, and the hydraulic limestone (water lime) beds were formed all the way across the State to the Hudson valley region. These water lime beds are quarried at many places along the line of outcrop across the State, but more especially in the famous Rosendale cement region (see plate 33). Next in order, and marking the summit of the Silurian, come the Cobleskill, Rondout, and Manlius limestones which, though not very thick, are remarkably persistent across the State.

As to the life of the Silurian seas it may be said that it was in effect the continued existence of the same organic groups that preceded in the waters of Ordovician time, though some diminished, some increased, and some new ones made their first appearance. Thus the graptolites and trilobites greatly diminished, while the echinoderms (star fishes) increased, and the brachiopods and mollusks held their own. Fossil seaweeds, but not animal remains, are common in the Oneida-Medina beds. Various fossils exist in profusion in the Clinton and Niagara formations, while in the middle Salina beds fossils are altogether absent because the water of that time was intensely saline. The waterlime beds at the base and top of the Salina are usually poor in fossils except for the remarkable assemblage of organic remains known as eurypterids which were scorpion-like creatures, and which are now wholly extinct. Fossils are generally rather common in the uppermost Silurian beds of the State.

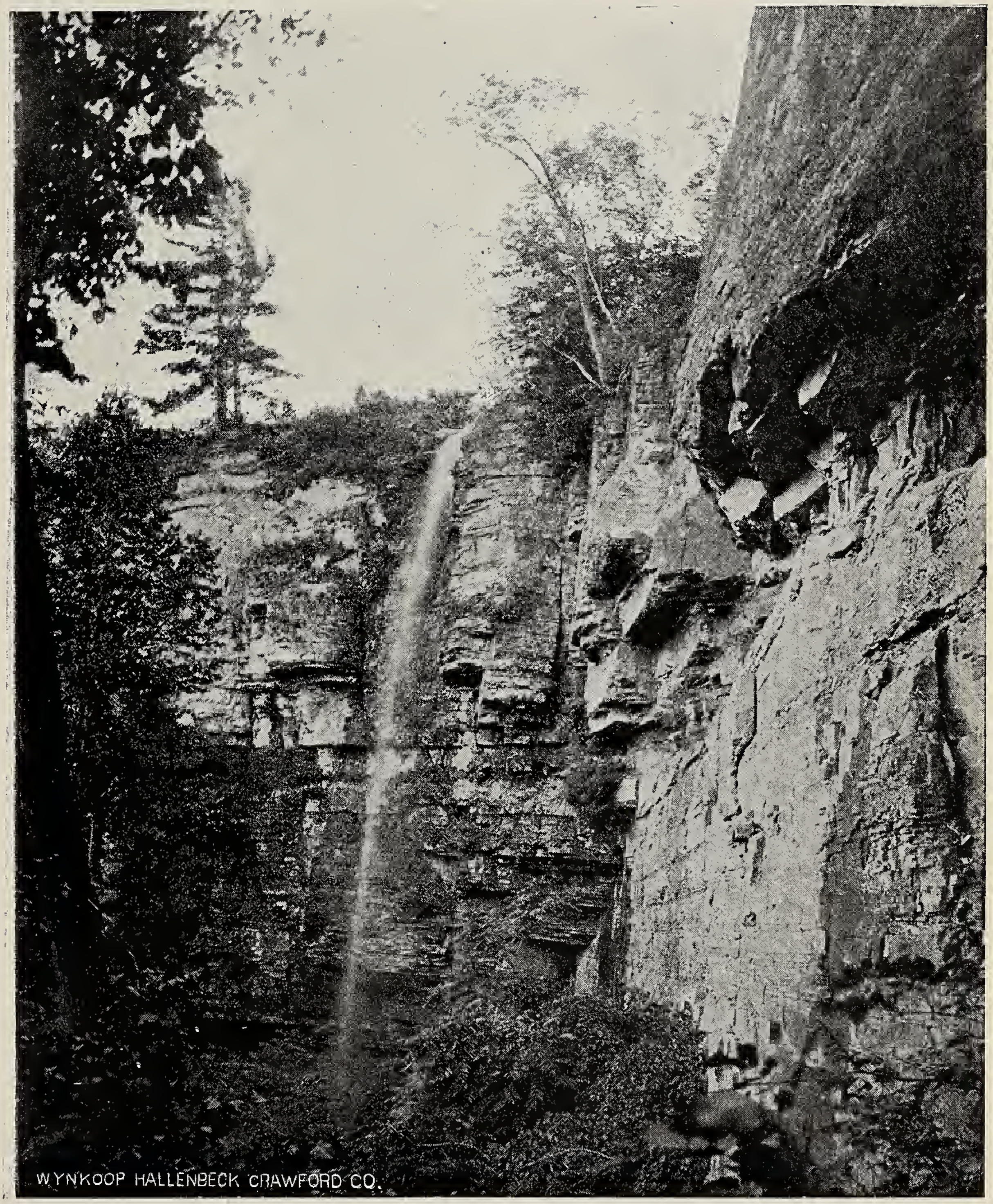
DEVONIAN AND CARBONIFEROUS PERIODS

The Devonian history of New York State is comparatively simple and the records are remarkably well shown in rocks of that age. *Devonian strata comprise the whole Catskill and Southwestern plateau provinces, except for a few small patches of Carboniferous rocks, and thus they cover more than one-third of the area of the State. They are more widespread on the surface than the rocks of any other age.* The combined thickness of the Devonian strata is over 4000 feet, which is considerably more than for the rocks of any other Paleozoic period in the State.

That the Devonian strata, on the Hudson valley side, formerly extended some miles farther eastward than they now do is proved by the presence of small outliers of Devonian rock, as illustrated by Becraft mountain just southeast of Hudson, the Rensselaer grit farther north and Skunnemunk mountain southwest of Newburg. During part of the time, the Devonian sea, or arms of it, reached as far east as these outlying masses and doubtless far beyond over the regions of Massachusetts and the Connecticut valley. The bold outcropping edges of thick Devonian strata in the Helderberg escarpment facing the Mohawk valley, and the Ontario plain, make it certain that the strata formerly extended some distance farther northward. It is more than likely that this northward extension of Devonian rocks was not beyond the southern border of the Adirondacks; at least we have no positive knowledge that the Devonian sea ever covered any of northern New York (see figure 18).

There was no disturbance of any kind at the close of the Silurian so that period passed very quietly into the Devonian. The Oriskany sandstone was for many years regarded as the base of the Devonian but now, as a result of a careful study of the fossils, the line between Silurian and Devonian is drawn just below the Helderberg limestone. As is the case with the Silurian, so here the rock formations are piled one upon another like great sheets and they all show a gentle southward dip (see figures 3 and 5). Beginning at the bottom the Helderberg limestone was succeeded in regular order by the Oriskany sandstone, Onondaga limestone, and Marcellus and Hamil-

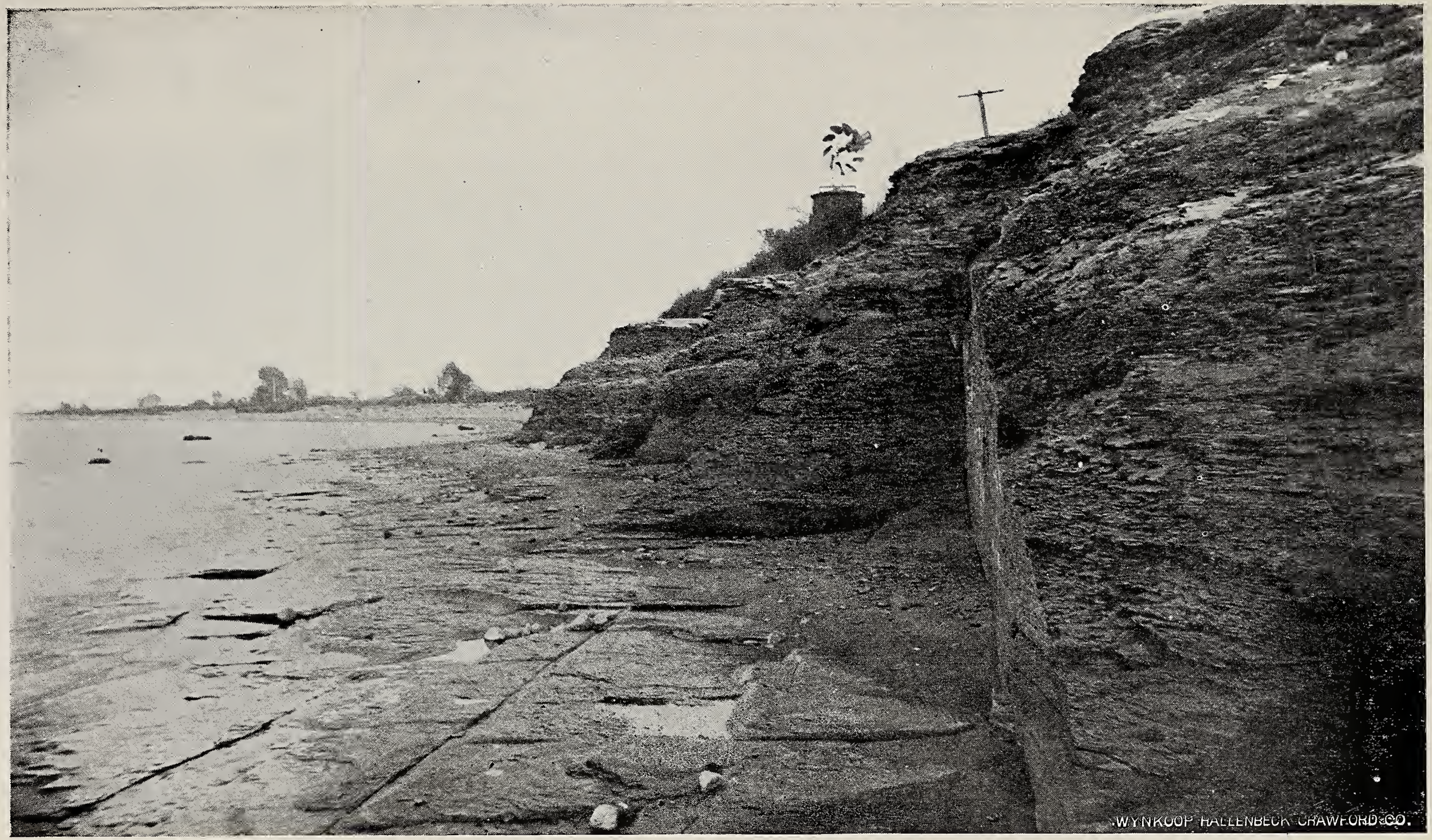
Plate 30



Cliff of Lower Devonian (Coeymans) limestone near Indian Ladder, Albany county

From N. Y. State Mus. Bul. 19, pl. 70

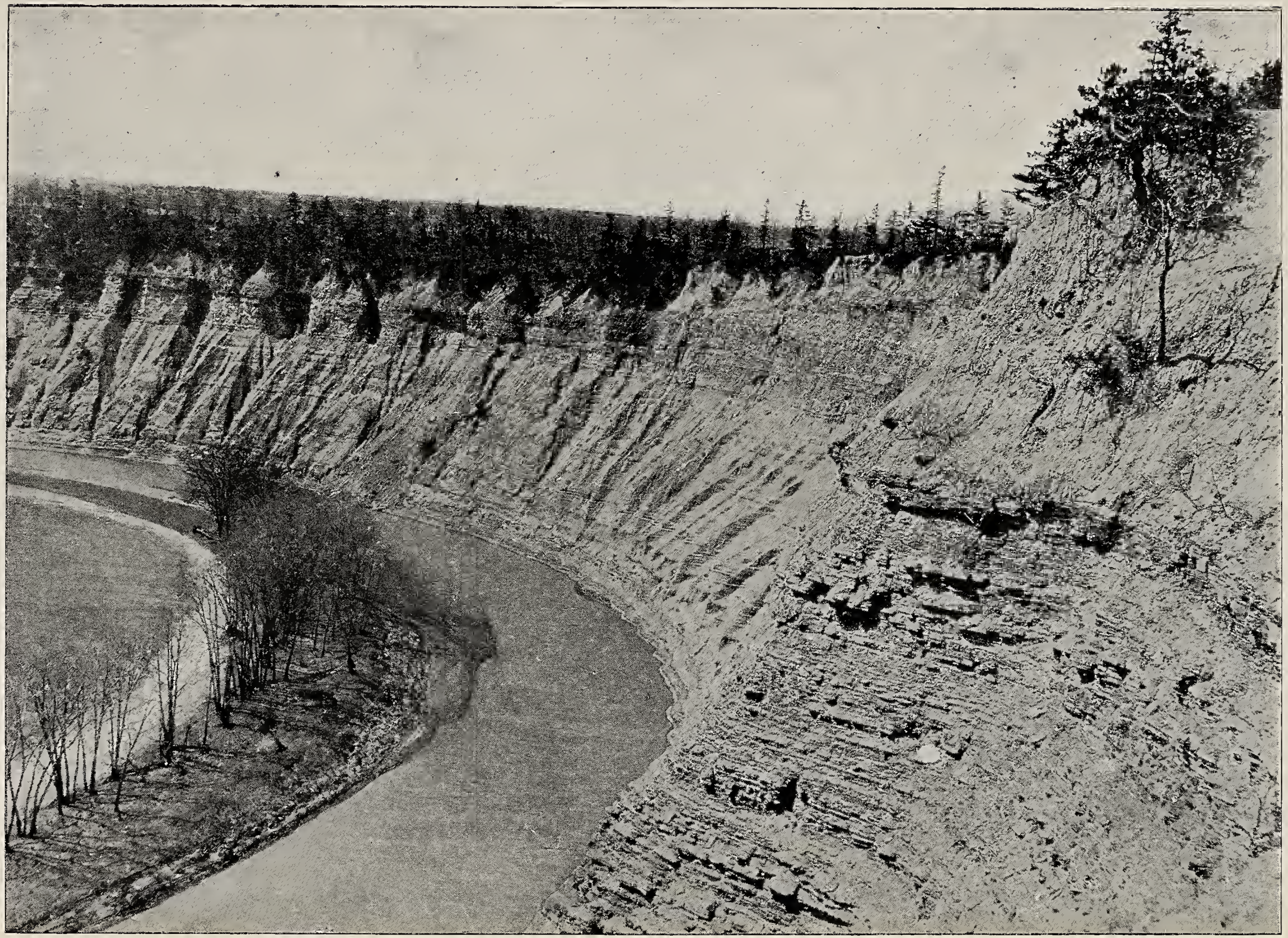
Plate 31



Marcellus and Hamilton (Devonian) shales outcropping along the shore of Lake Erie at Athol Springs, Erie county. The rock is dark colored and in thin layers. The smooth, vertical walls are due to a breaking off of rock masses along what are called "joint planes" and which are so common in nearly all rock ledges.

From N. Y. State Mus. Bul. 19, pl. 72

Plate 32



Upper Devonian (Cashaqua and Rhinestreet) shales in the gorge of the Genesee river near Mount Morris. The thin bedded and stratified character of these rocks are well shown.

From N. Y. State Mus. Bul. 118, pl. 4

ton shales, all of which were deposited over the whole Devonian basin in New York. Above these come the Tully limestone and Genesee shale which extend from east-central to western New York. Still higher, and forming the summit of the Devonian, are the Portage shales and sandstones and the Chemung (or Catskill) sandstones which extend from the Catskill mountains to western New York.

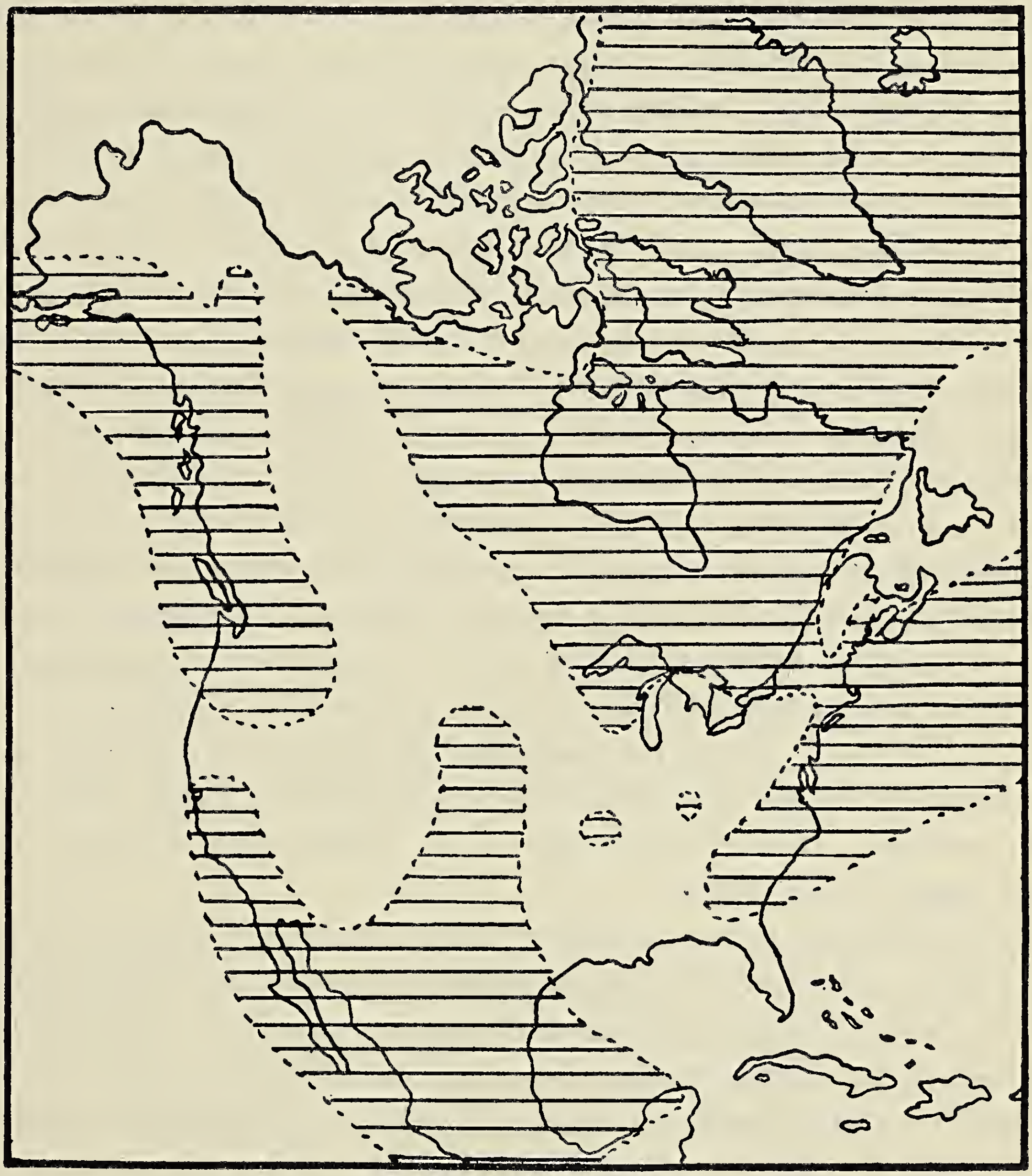


FIG. 18 Generalized map of North America in the Devonian period, showing the relations of land and water. Horizontal lined areas = land; blank areas = water. Only the northern and extreme southeastern portions of the New York State area were land. The western shore of Appalachia was farther west than during the Ordovician, due to the addition of the Taconic mountain area.

Except for the comparatively thin Tully formation, the limestone is confined to the Lower Devonian and the lower part is not more than a few hundred feet thick. Thus the great bulk of Devonian rock lies above this limestone, and it consists of shales and sandstones piled layer upon layer. These latter rocks are clearly land-derived sediments which were washed into the Devonian sea by streams from the Taconics, and also probably from land areas which are known to have existed to the north in Canada.

The Devonian strata, from oldest to youngest, abound in the fossils of marine organisms, and some fossil land plants have also been found. Looked upon in a broad way, Devonian life was much like that of the Silurian, though certain fundamental differences are to be noted. Thus the Devonian furnishes the first really authentic evidence of the existence of land plants. Such plants as seed-ferns, lycopods (club mosses), and equisetae (horse tails) grew to be large treelike forms and in considerable profusion. Remains of these have been found in the Devonian strata in New York. All of them belonged to the very simple, nonflowering plants and were closely related to the plants of the next succeeding Carboniferous (coal) period. Among the fossil animals especially abundant in the Devonian rocks of the State are: sponges, corals, echinoderms (star fishes), brachiopods, mollusks (including the bivalves, gastropods, cephalopods), and arthropods (including trilobites and eurypterids). The graptolites became almost extinct during the Devonian. One of the remarkable features of the life was the great abundance and varity of fishes, so that this period is commonly referred to as the "Age of Fishes." From the zoological standpoint all the fishes were of simple types, the true bony skeletons of modern fishes not having been evolved. Devonian fish remains in considerable numbers have been found in the State.

Carboniferous strata are only sparingly represented in New York, there being a few small outlying masses in the southwestern portion of the State (Cattaraugus and Allegany counties). Immediately southward in Pennsylvania, Lower Caboniferous strata are developed on a great scale, so we can be certain that the early Carboniferous sea spread over the southern border of New York State. It is quite possible that this sea extended over most of southern New York, but positive evidence due to absence of strata is lacking.

The Permian is the last great period of the Paleozoic era, but rocks of that age are nowhere present in New York State.

APPALACHIAN MOUNTAIN REVOLUTION (CLOSE OF THE PALEOZOIC)

The Paleozoic era was brought to a close by one of the most profound physical disturbances in the history of North America. It has been called the Appalachian revolution because at this time the Appalachian mountain range was born out of the sea by upheaval and folding of the strata. Because of the direct effect of this great upheaval upon the history of New York State, a brief description is given.

All through the vast time (probably at least ten million years) of the Paleozoic era, a great land mass existed along what is now the eastern coast of North America. This land, which has been called Appalachia, had its western boundary approximately along the present coast line, while it must have extended eastward at least as far as the present border of the continental shelf. Concerning the altitude and character of the topography of Appalachia we know almost nothing, but we do know that it consisted of rocks of Precambrian age, and very similar to those of the Adirondacks. The tremendous amount of derived sediments shows that Appalachia was high enough during nearly all its history to undergo vigorous erosion. Although oscillations of level more than likely affected Appalachia, and its western shore line was quite certainly somewhat shifted at various times, nevertheless it persisted as a great land-mass with approximately the same position during all of its long history. Its general position is well shown on the map, figure 16.

Barring certain minor oscillations of level, all of the region just west of Appalachia was occupied by sea water during the whole Paleozoic era, and sediments derived from the erosion of Appalachia were laid down layer upon layer upon that sea bottom. The coarsest and greatest thickness of sediments accumulated nearest the land, that is along what we might call the marginal sea bottom. At the same time finer sediments, in thinner sheets, were being deposited all over the Mississippi valley region. By actual measurement, in the present Appalachians, we know that the maximum thickness of these sediments was at least 25,000 feet. The strata are all of comparatively shallow water origin, as proved by the coarseness of sediment, ripple marks, fossil coral reefs, etc., and so we are forced to conclude that this marginal sea bottom gradually sank during the process of sedimentation, thus producing what is called a great geosynclinal trough. Perhaps the very weight of accumulating sediments caused this sinking. Finally, toward the close of the Paleozoic era, sinking of the marginal sea bottom and deposition of sediments ceased, and "eventually the trough began to yield to lateral compression and its contained strata were thrown into folds or fractured by great overthrusts. Thus in place of a sinking sea bottom along the shore of the great interior sea, arose the Appalachian mountains, which in their youth may have been a very lofty range rivalling the Alps in height. This range extends from the mouth of the St Lawrence river to Alabama."[1] As a result of this great physical revolution practically all of eastern North America was raised well above sea level, though the more moderately elevated Mississippi valley region was unaccompanied by folding or faulting of the strata.

The effect of the Appalachian revolution upon New York State is a matter of fundamental importance because the whole State was raised well above the sea, and true marine conditions never again prevailed over any part of its area except the extreme southeastern portion.[2] Judging by the vast amount of erosion which took place during the succeeding Mesozoic area, we are safe in our belief that the general elevation of the State at the close of the Paleozoic was at least several thousand feet above sea level. It is also important to note that this great uplift in New York was accomplished without any folding of the strata except in the lower Hudson valley region. The gentle southward to southwestward tilt (dip) of the Paleozoic strata from the Catskill Mountains westward is, however, thought to have been produced at this time due to somewhat greater uplift on the north.

Along the western side of the Hudson valley, folds produced at the time of the Appalachian revolution are plainly visible, though the folding of the rocks here was much less violent than in the Appalachians proper. As a matter of fact these folds are but continuations of those of eastern Pennsylvania, but the compressive force was too weak to cause much disturbance. Professor Davis has aptly styled these, "Little mountains east of the Catskills." By far the most conspicuous physiographic feature of this folded region is the Shawangunk mountain (ridge) which stands out so prominently and whose very existence is due to the fact that, as a result of the folding and subsequent erosion, the great

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[1] Scott's Introduction to Geology, second edition, p. 647.

[2] The influx of tide waters along the eastern and northern borders of the State in the Quaternary period presents no exception to this statement because the conditions then were estuarine rather than marine.

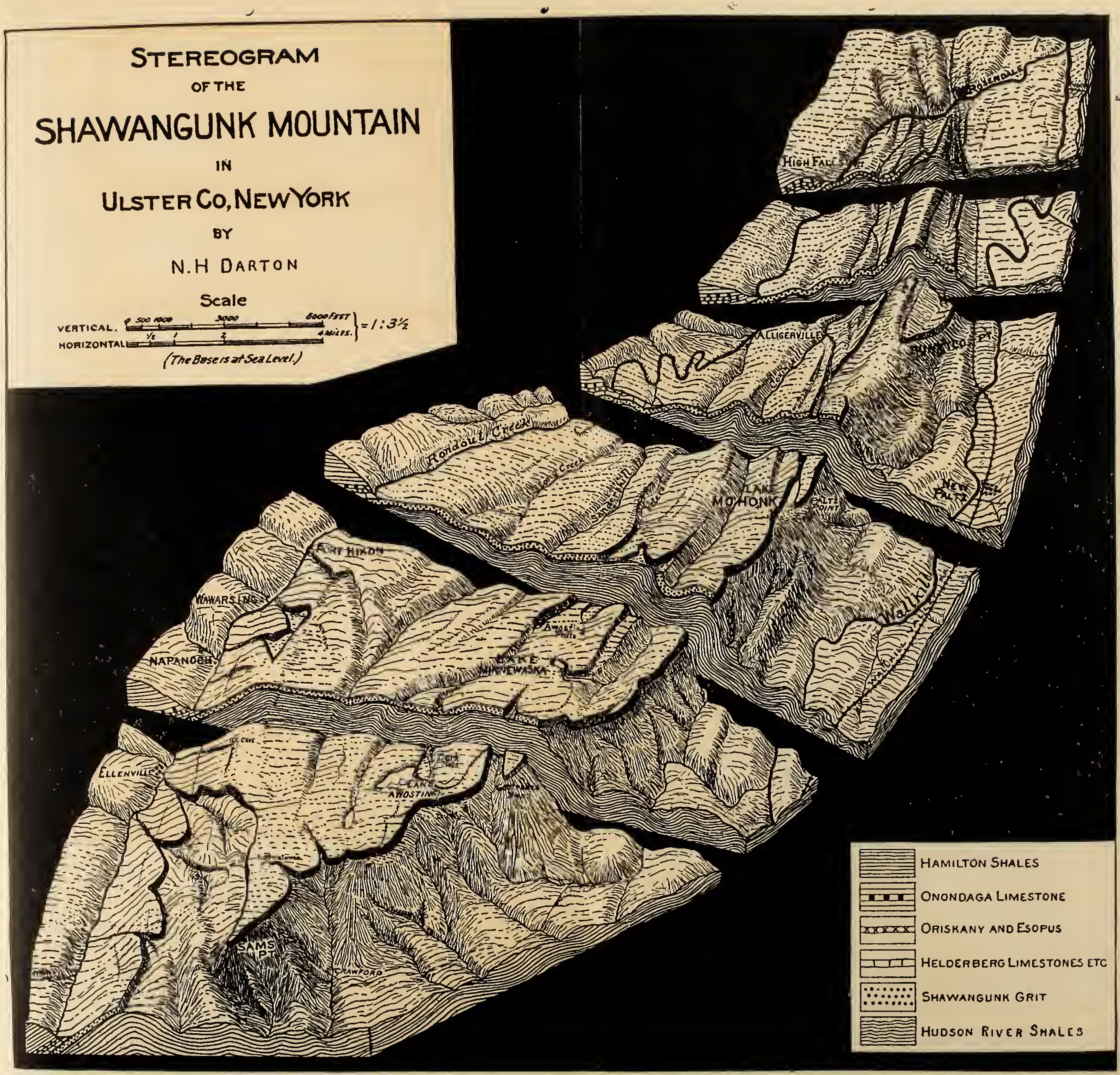


FIG. 19 The main body of the mountain consists of a great thickness of folded Ordovician (Hudson River) shales and sandstones which are capped by a comparatively thin, but very resistant layer of Shawangunk conglomerate.

After Darton N. Y. State Mus. Rep't 47, 1894, facing p. 540

sheet of hard and resistant conglomerate has been left as a protective cap over the soft Hudson river (Ordovician) shales (see figure 19). In the Rosendale cement region the effects of the folding are also evident (see figure 10 and plate 33). The folds in the Silurian and Devonian strata of Skunnemunk mountain were also produced at this time. The whole lower Hudson valley region was subjected to this compressive force but, since all the rocks older than the Silurian were already so greatly disturbed, it is often impossible to see the effects of the Appalachian disturbance. Thus we see that mountain-building forces have affected the rocks of the Highlands-of-the-Hudson at least three times (Precambrian, Taconic revolution, and Appalachian revolution); Cambrian and Ordovician strata of the lower Hudson valley twice (Taconic and Appalachian revolutions); and the Silurian and Devonian strata but once (Appalachian revolution).

The extensive faulting or fracturing of the eastern Adirondack and Mohawk valley regions is a matter of no small importance in our discussion of the physical history of the State, because the present major topographic features of those regions are largely dependent upon the faulting. It is generally believed that much of this faulting occurred toward the close of the Paleozoic area, and most likely at the time of the Appalachian revolution, but since considerable faulting certainly occurred later than that time, it is thought best to discuss this whole subject toward the close of the next chapter.

Chapter 5

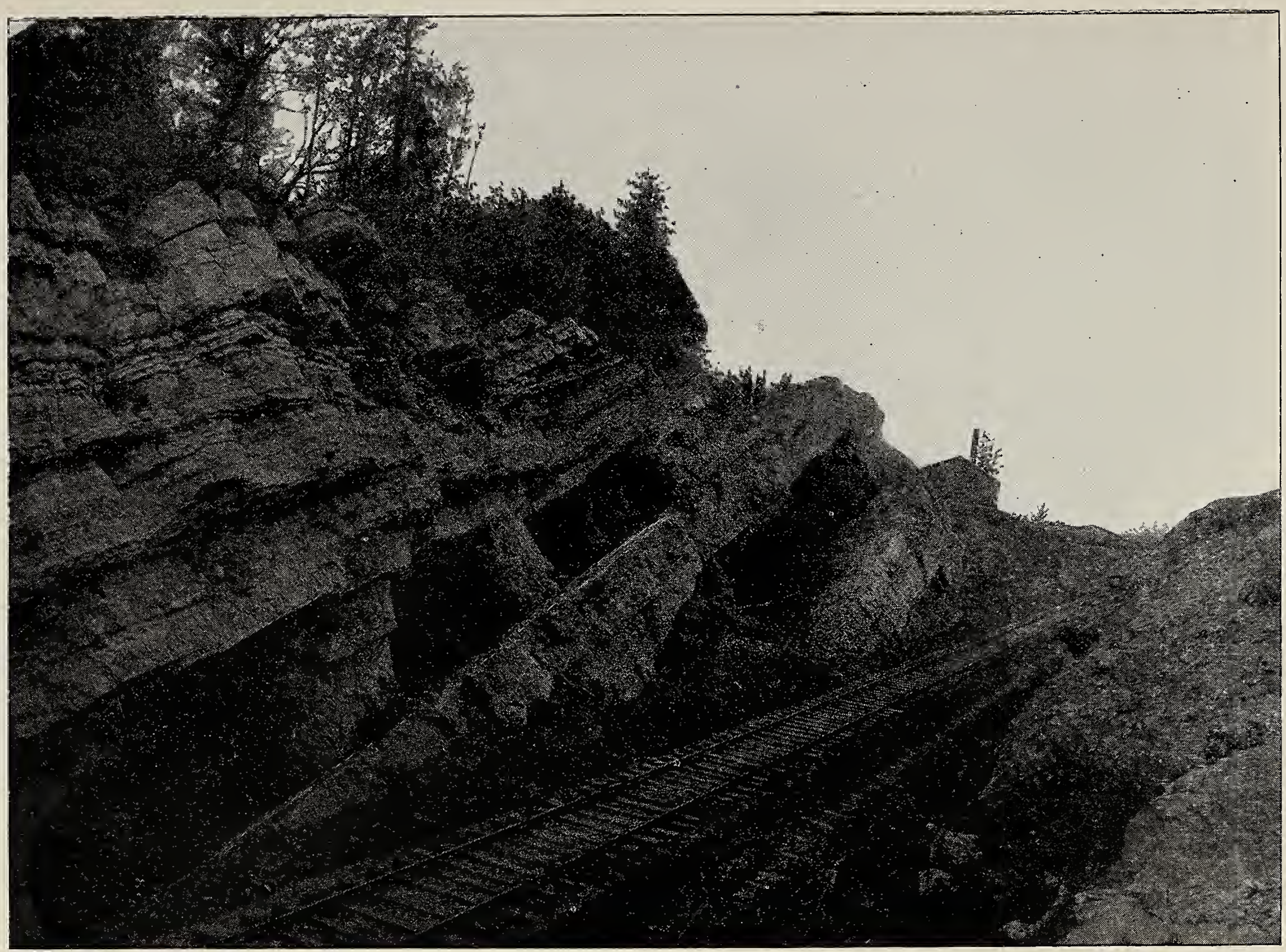
MESOZOIC HISTORY

TRIASSIC PERIOD

We have observed that, as a result of the Appalachian revolution, New York State was raised well above sea level, and, so this was its condition at the opening of the Triassic period. The total absence of any Triassic strata of marine origin makes of it quite certain that the continent extended farther eastward than it does today, and, if so, the old Paleozoic land-mass called Appalachia still existed in Triassic time, though probably much diminished in height by that time. The absence of marine rocks, however, does not mean that no deposition of Triassic sediments occurred within the borders of the State, because a remarkable series of nonmarine strata which accumulated along the Atlantic slope are, in part, shown in southeastern New York (Rockland county and Staten Island).

These nonmarine strata are of Upper Triassic age, as told by the fossils, and their present distribution and mode of occurrence clearly show that they were deposited in a series of long troughlike depressions whose trend was parallel to that of the main axis of the Appalachian range. These troughs lay between the Appalachians proper and old Appalachia. The latter also was then partly made up of the greatly worn-down Taconics. One of these troughs extends along the Connecticut river through Connecticut and Massachusetts; another, and the largest, reaches from Rockland county, New York, through northern New Jersey, southeastern Pennsylvania, Maryland, and into northern Virginia, while several smaller ones lie in Virginia and North Carolina. These depressions were most favorably situated for rapid accumulation of thick deposits because of their position immediately between the two great land masses which were being eroded. The sediments derived from the erosion of the young Appalachians were especially abundant because of the vigorous wearing down of the young mountains. A thickness of thousands of feet of nonmarine rocks, mostly red sandstones and shales, was finally accumulated in these basins. These rocks are known as the Newark series. The great thickness of these rocks, from 10,000 to even possibly 15,000 feet, strongly argues for a gradual downwarping, or downfaulting of the basins as deposition of sediments went on. It is often stated that these

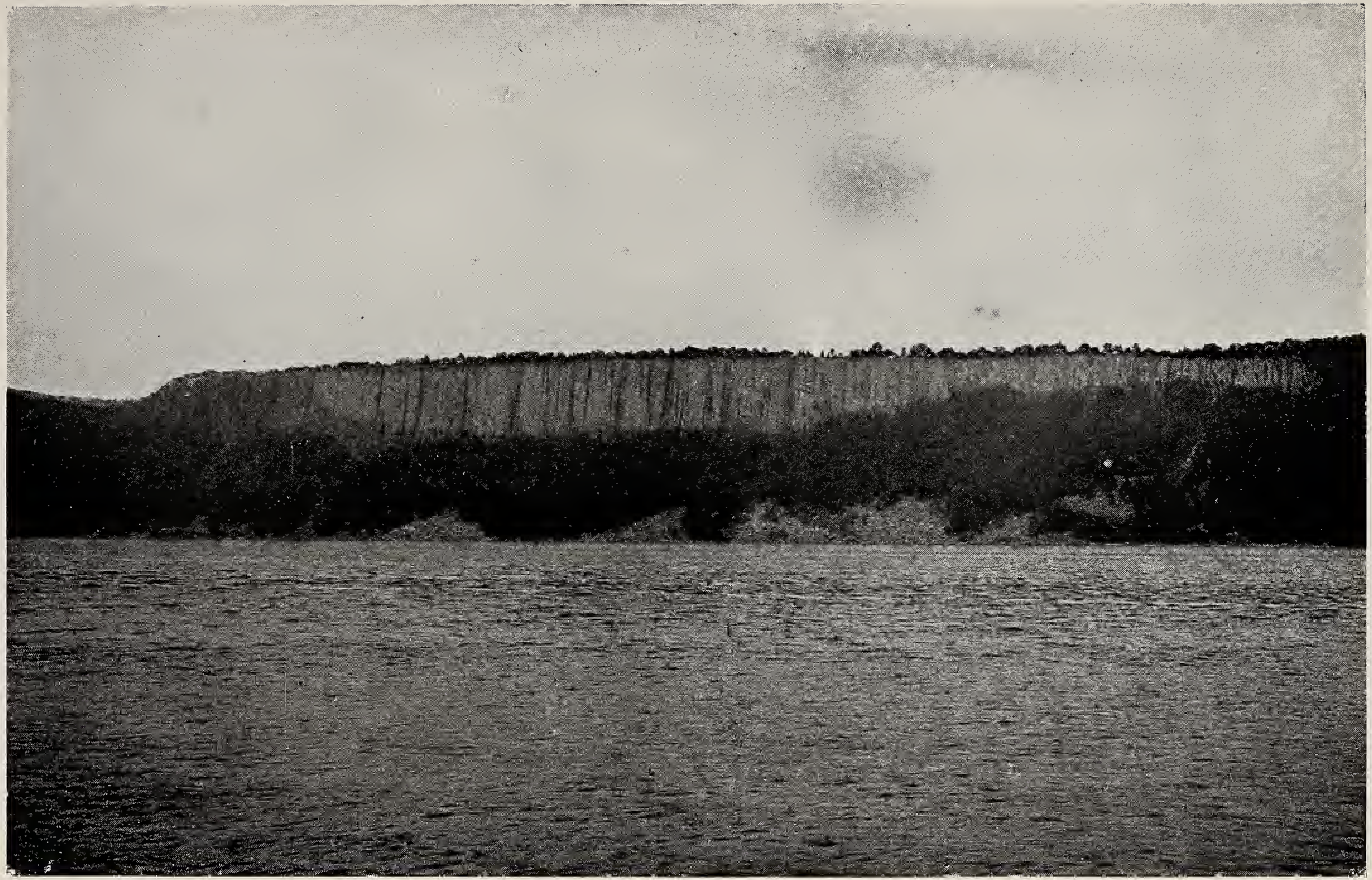
Plate 33



Hydraulic limestone or waterlime of Salina (Silurian) age at the cement quarries 1 mile south of Whiteport, Ulster county. The pronounced tilt of the strata was given at the time of the Appalachian revolution.

From N. Y. State Mus. Bul. 19, pl. 116

Plate 34



Palisades-of-the-Hudson, as seen from Hastings, Westchester county. The rock is a sort of dark-colored lava (diabase) which presents a crude columnar structure and rests upon sandstone of Triassic age. The sandstone is largely concealed by the rock débris just above the river level.

From N. Y. State Mus. Bul. 19, p. 4

strata were formed in estuaries, but at least in the northern area, from the Connecticut valley to Maryland, many of the layers show sun cracks, rain-drop pits, ripple marks, and remains and footprints of land reptiles. These features show that for the most part the beds were formed in very shallow water such as flood plains or lakes where changing conditions frequently allowed the surface layers to lie exposed to the sun.

During the time of the deposition of the Newark beds there was considerable igneous activity as shown by the occurrence of sheets of igneous rocks within the mass of sediments. In some cases true lava flows, with cindery tops, were poured out on the surface and then became buried under later sediments, while in other cases the sheets of molten rock were forced up either between the strata or obliquely through them, thus proving their intrusive character. As a result of subsequent erosion, these lava intrusions often stand out conspicuously as topographic features. Perhaps the most noteworthy of these is the great igneous rock sheet, part of which outcrops to form the famous Palisades of the Hudson, and which is exposed for a distance of seventy miles. As shown in figure 20, the molten rock sheet first broke through the strata and then crowded its way along parallel to them. During the process of cooling there was contraction which expressed itself by breaking the rock mass into great, crude, vertical columns, and hence the origin of the name "Palisades" (see plate 34). At the base of the Palisade rock, as well as on its top a little back from the edge of the cliff, the Newark sandstone outcrops. The steep cliff is due to the fact that the hard igneous rock is much more resistant to erosion and weathering than the sandstone above and below it.

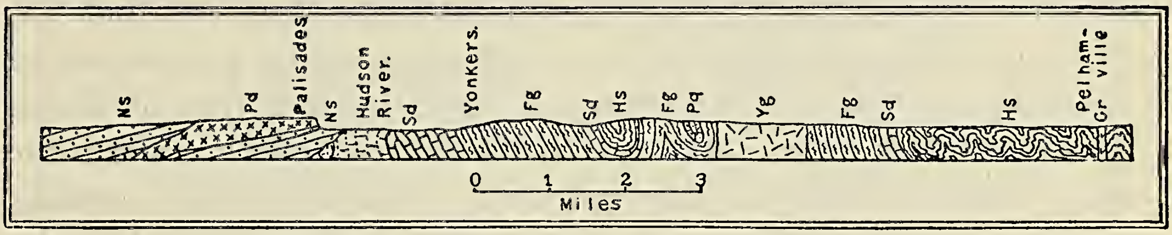


FIG. 20 Detailed section running west-northwest through Pelhamville, Yonkers and the Palisades in southeastern New York, showing the folding of the rocks, the granite dikes, and the relation of the Palisade lava to the other formations. Fg = Fordham gneiss (Precambrian); Hs = Hudson or Manhattan schist; (Precambrian); Yg = Yonkers gneiss; Gr = granite dike; Ns = Newark sandstone (Triassic); Pd = Palisade diabase or lava (Triassic).

Modified from New York City folio, U. S. G. S.

The rocks of the Newark series are nearly everywhere tilted and extensively fractured by normal faults. Just when this deformation occurred is not exactly known, but it was probably at the close of the Triassic period as will be shown under the next heading.

Briefly summarized, *the Triassic was a time of accumulation of thick deposits of red sandstone and shale of nonmarine character in troughlike depressions along the Atlantic slope, these deposits being represented in southeastern New York. During their formation there was considerable igneous activity when sheets of lava were forced through or between the strata as is well shown in the case of the rock of the Palisades.*

JURASSIC PERIOD

No rocks of Jurassic age occur within New York State nor, as a matter of fact, in all of eastern North America, except possibly some fresh-water deposits along the Potomac river of Maryland. The failure of such strata is readily explained by the fact that the Jurassic period was ushered in by a slight upwarping (accompanied by faulting and tilting of the rocks) of the Atlantic border of North America so that there were no basins of deposition within the present eastern border of the continent. That this uplift actually occurred and that the Jurassic period in the eastern United States was a time of extensive erosion, is well established because the whole Atlantic seaboard, including the tilted and faulted Triassic strata, was worn down well toward the condition of a peneplain and the next sediments (Cretaceous) were deposited upon the eastern portion of that worn-down surface (see figure 22). For instance, on Staten Island and in northern New Jersey, the Cretaceous beds may be seen resting directly upon the deeply eroded Triassic rocks, and hence the proof is conclusive that during much if not all of the Jurassic period active erosion was taking place, and this in turn implies that the Triassic beds were well elevated in the early Jurassic.

Briefly summarized: *No deposition of Jurassic strata occurred within the borders of New York State, but, instead, the region was well above water and undergoing active erosion so that by the close of the period this region, as well as the whole Atlantic slope, had been worn down to the condition of a fairly good peneplain.*

CRETACEOUS HISTORY

The Cretaceous period opened with the eastern coast line of the eastern United States somewhat farther out than it now is, but early in that period there was enough subsidence, or possibly warping, of the coastal lands to allow deposition of sediments over much of the region now known as the Atlantic Coastal plain. That little downwarping of the surface was necessary in order to produce proper conditions for sedimentation is evident because the coastal lands, just prior to the Cretaceous, were already low-lying as a result of the long Jurassic erosion period. There was just enough

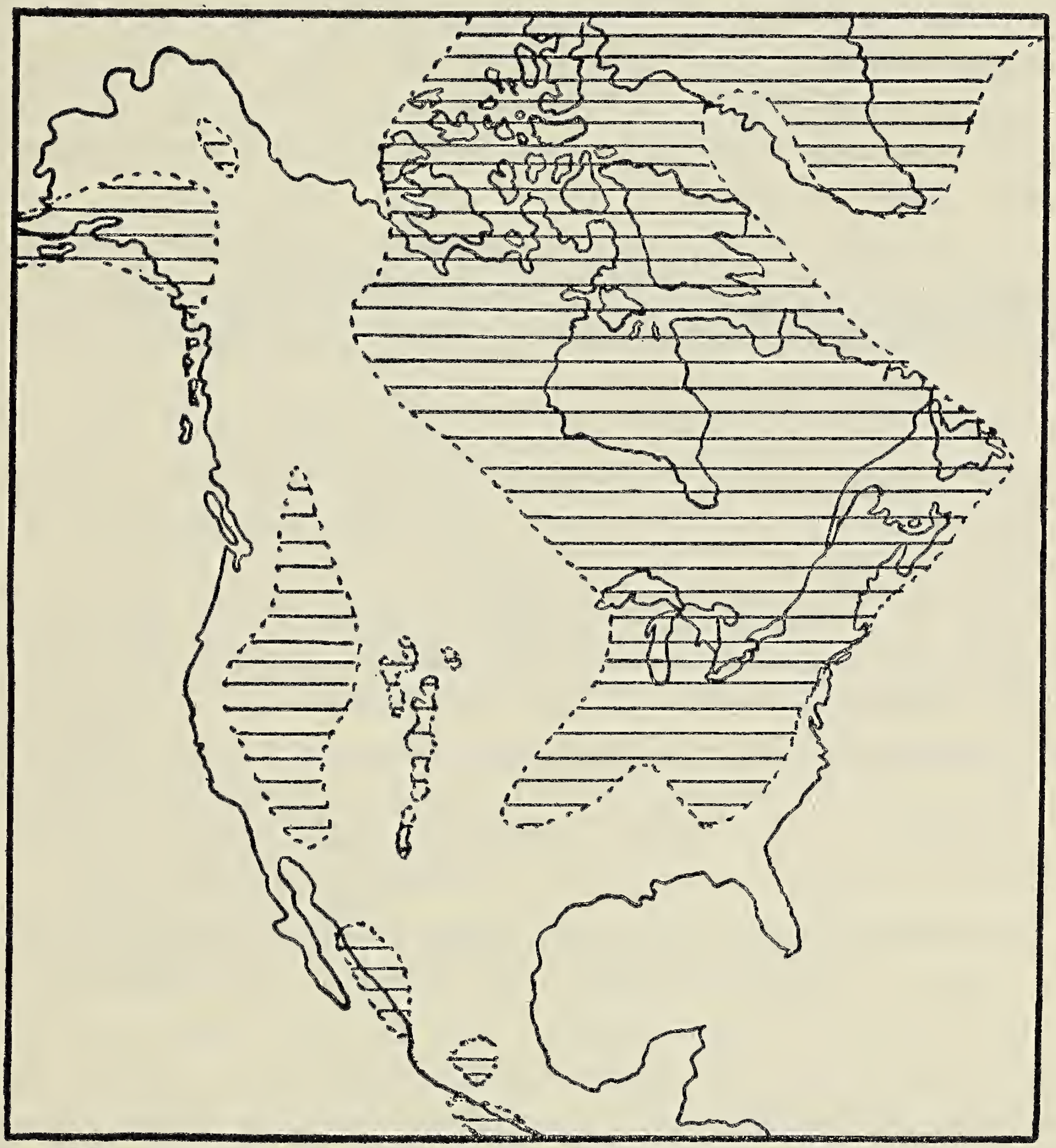


FIG. 21 Generalized map of North America in the Upper Cretaceous period, showing the relations of land and water. Horizontal lined areas= land; blank areas=water. The sea then spread over the Atlantic coastal plain region including Long and Staten Islands of New York. During the next (Tertiary) period, the conditions were much the same along the Atlantic and Gulf coasts, but in the west the great interior sea had disappeared.

warping of these low coastal lands to produce wide flats, flood plains, shallow lakes, and marshes back from the real coast line, and in them were deposited the sediments derived from the Piedmont plateau and Appalachian areas. The early Cretaceous deposits thus formed are known as the Potomac series, and they consist of very irregular layers of sand, gravel, and clay. The very irregular arrangement of these beds, and their rich content of fossil land plants, afford conclusive evidence that the sediments were not accumulated under marine conditions. The Potomac series outcrops at the western margin of the present Coastal plain, and it has been traced from Martha's Vineyard, through Nantucket, Long Island, Staten Island, Northern New Jersey, and southward into Georgia. Passing seaward the strata dip under those of later age (see figure 22). On Long Island, Potomac outcrops occur only along the northwestern border, but these beds no doubt dip under the more recent deposits of the rest of the island. The maximum thickness of the Potomac series is only about 700 feet.

Along the Atlantic coast certain deposits which should come between the Lower and Upper Cretaceous are missing, and the Upper Cretaceous beds rest upon the eroded surface of the otherwise undisturbed Lower Cretaceous. Thus we know that there was a gentle upward oscillation of the land toward the end of the Lower, or beginning of the Upper, Cretaceous, after which a moderate amount of erosion of the Lower Cretaceous beds took place.

Then came another gentle submergence of the coastal lands when the Upper Cretaceous strata were formed. The character and present extent of these deposits, and the fact that they are of marine origin, prove that this subsidence allowed a shallow sea to spread over practically all of what is now called the Atlantic Coastal plain including most of Long and Staten Islands in New York. *Accordingly we learn that, for the first time since the close of the Paleozoic, did truly marine conditions prevail over any portion of New York State, and also that Appalachia, the great land mass of the east, which had persisted through the many million years of the Paleozoic and most of the Mesozoic, now disappeared under the Cretaceous sea.*

The present surface distribution of the Upper Cretaceous beds is much like that of the Lower Cretaceous, and they also dip under the still later formations of the Coastal plain (see figure 22). The thickness of the Upper Cretaceous is never more than a few hundred feet.

To summarize: *The Cretaceous period opened with slight subsidence of the Coastal plain region, including southeastern New York, to produce low-lying flats upon which the nonmarine Potomac sediments were deposited. Then came a slight reelevation (accompanied by erosion) followed by subsidence of the Coastal plain region enough to allow encroachment of the shallow sea in which the Upper Cretaceous sediments were accumulated.*

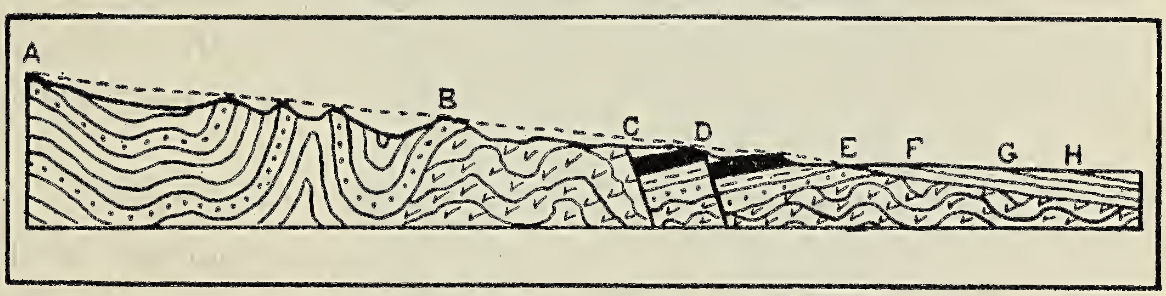


FIG. 22 Diagrammatic section through the Atlantic slope, at about the latitude of northern New Jersey, showing the structures and relations of the various physiographic provinces as they now exist.

A to B = Folded Paleozoic strata of the Appalachian mountains, with hard strata standing out to form the ridges.

B to C = Piedmont plateau consisting of highly folded and metamorphosed rocks of Precambrian and early Paleozoic ages.

C to E = Triassic strata showing titlting and faulting of the beds and mode of occurrence of an igneous rock sheet (D) which outcrops to form a low ridge.

E to H = Coastal plain, consisting of comparatively thin sheets of unconsolidated sediments.

E to F = Cretaceous beds (upper and lower).

F to G = Tertiary beds.

G to H = Quaternary beds.

H = Present coast line.

The dotted line represents the peneplain character of the surface (except for the tilting) at the close of the Cretaceous period.

LIFE OF THE MESOZOIC

The life of the Mesozoic is but scantily represented within New York State because rocks of that age are so poorly exposed. The Mesozoic era is commonly referred to as the "Age of Reptiles" because animals of that class then reached their culmination of development. During this era the great dinosaur reptiles, the largest land animals that every lived, stalked the western plains. Some remains of smaller dinosaurs have been found in the Triassic beds of the Atlantic coast, one specimen lately having been discovered in the Newark beds along the lower Hudson. Reptilian tracks abound in the Newark strata. Mammals appeared in the early Mesozoic, but throughout the era they continued small and comparatively insignificant. The first birds and true bony fishes (teleosts) appeared in the later Mesozoic, but they are either absent or not important in the Mesozoic of the middle Atlantic coast. The invertebrate life of the era was in general very different from that of the Paleozoic, few types from the latter era having persisted, and by the end of the Mesozoic the invertebrates took on a decidedly modern aspect.

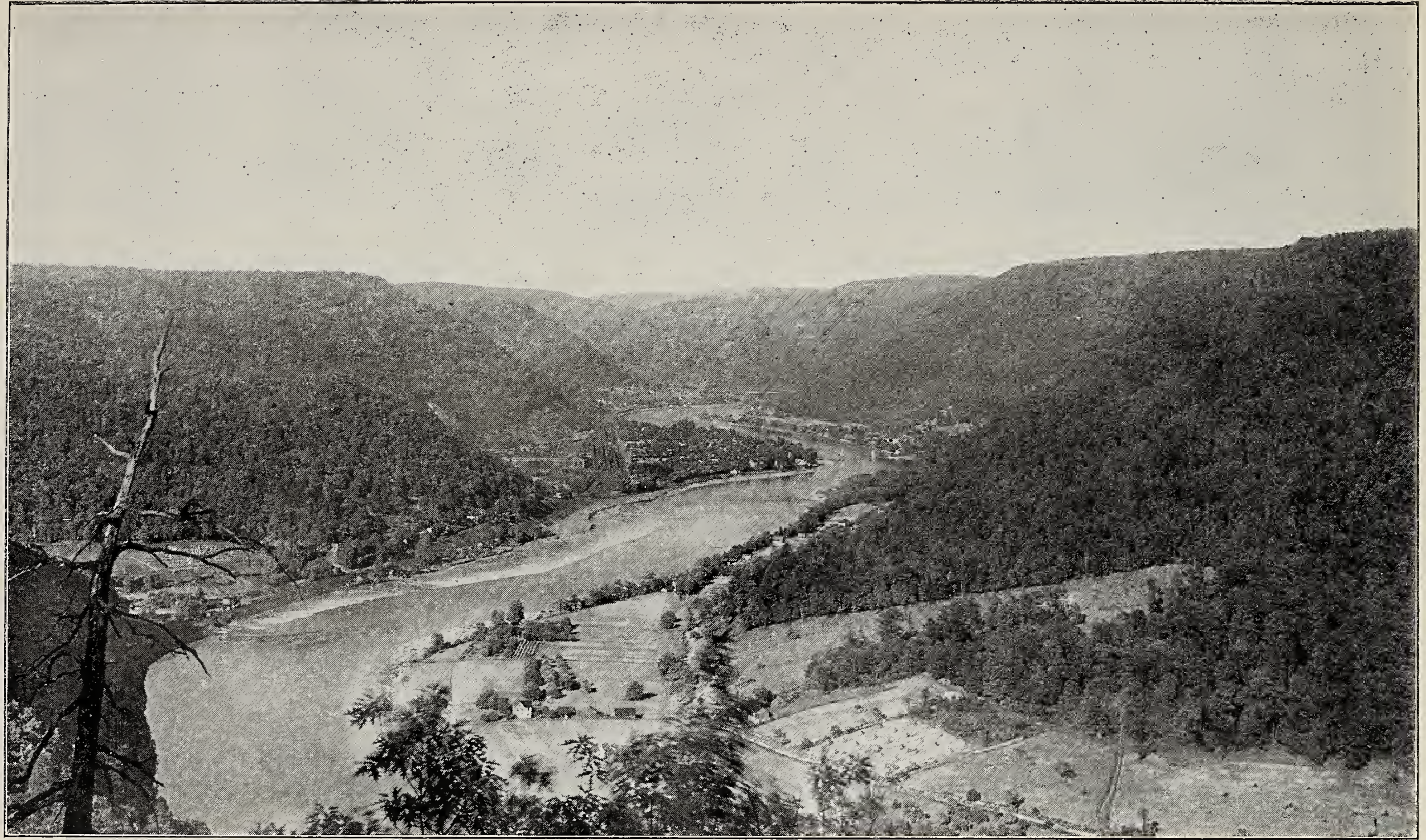
Among plants, those of the early era were still simple nonflowering kinds much like those of the Carboniferous or "Coal age," while in the late Mesozoic flowering plants of very modern types, including many of our present forest trees, were prominently developed. The Cretaceous beds of the Atlantic coast are rich in fossil plants.

THE CRETACEOUS PENEPLAIN AND ITS UPLIFT

During the Mesozoic era most of the eastern portion of the United States was above water and undergoing erosion, so that, as a result of this very long period of wear, the region was reduced to the condition of a more or less perfect peneplain. It is known as the Cretaceous peneplain because of its best development during the Cretaceous period. This vast plain extended over the areas of the Appalachian mountains, Piedmont plateau, all New York State, the Berkshire hills, and the Green mountains. Its most perfect development was in the northern Appalachians, for example, from east-central Pennsylvania to Virginia, where hard and soft rocks alike had been so thoroughly cut down that no masses projected notably above the level of the low-lying plain.

Farther northward, however, over New York and western New England, its development was less perfect so that certain masses of harder rock stood out more or less prominently above the general level of the plain. In the central and eastern Adirondacks many low mountains of very resistant igneous rock rose above the peneplain surface. In a similar manner an occasional low mountain stood out in the Berkshire Hills region, and it seems probable that the hard Devonian sandstones of the Catskills also rose notably above the peneplain, though in the latter case positive proof has not been given. Thus, *toward the end of the Mesozoic era all the area of New York State had been reduced to a vast, monotonous, featureless plain (peneplain) except for the mountain masses of very moderate elevation in the east-central Adirondack, and possibly also the Catskill, regions.* As Professor Berkey says: "The continent stood much lower than now. Portions that are now mountain tops and the crests of ridges were then constituent parts of the rock floor of the peneplain not much above sea level. This rock

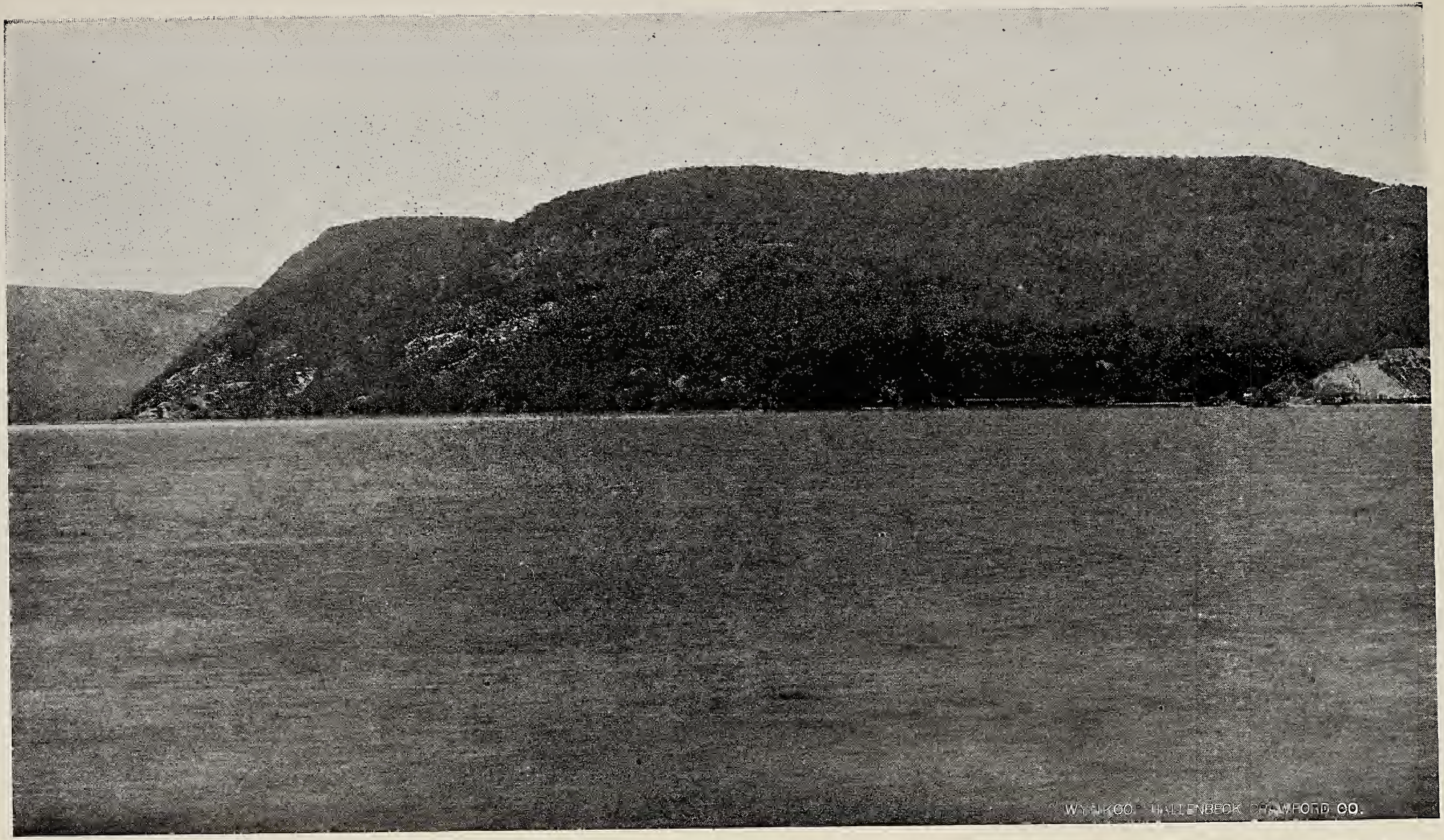
Plate 35



Looking eastward down the valley of the west branch of the Susquehanna river from a point 2 miles west of Renovo, Clinton county, Pa. The river here cuts across a series of Appalachian ridges and the view was taken from near one of the summits. The remarkable concordance of altitudes or "even sky line" of the ridges is well shown and this uniform level of the ridge tops represents the surface of the upraised Cretaceous peneplain.

Photo loaned by W. M. Gaylor, Sag Harbor, N. Y.

Plate 36



Precambrian rock in the Highlands of the Hudson. Anthony's Nose and Manitou mountain along the Hudson river. The fairly even sky line of the mountain summits represents the old, upraised Cretaceous peneplain.

From N. Y. State Mus. Bul. 19, pl. 8

floor was probably thickly covered with alluvial deposits (flood plain) not very different in character from the alluvial matter of portions of the lower Mississippi valley of today. Upon such a surface the principal rivers of that time flowed, sluggishly meandering over alluvial sands and taking their courses toward the sea (the Atlantic) in large part free from influence by the underlying rock structure. The ridges and valleys, the hills, mountains and gorges of the present were not in existence, except potentially in the hidden differences of hardness of rock structure. Such conditions prevailed over a very large region, certainly all of the eastern portion of the United States."[1]

In the western part of the United States the Mesozoic era was brought to a close by what must take rank as one of the greatest mountain upheavals in the history of North America. This is known as the Rocky Mountain revolution because the great Rocky Mountain system was chiefly formed at this time. At the same time *the Mesozoic was closed in the eastern part of the United States by an important physical disturbance though on a far less grand scale than that in the west. This disturbance produced an upwarp of the vast Cretaceous peneplain with maximum uplift of from two to three thousand feet following the general trend of the Appalachians, and thence through northern New York.* This upward movement was unaccompanied by any renewed folding of the strata, and the effect was to produce a broad dome sloping eastward and westward, and northward to the Gulf of St Lawrence and southward to the Gulf of Mexico.

A prominent effect of this great uplift was to revive the activity of the streams so that they once more became active agents of erosion. *We are now prepared to make the important statement that the present major topographic features of New York State, as well as of western New England and the whole Appalachian region, have been produced largely by the erosion or dissection of this upraised Cretaceous peneplain.* This being the case, are any remnants of that upraised surface still left? In the affirmative answer to this inquiry we have the most positive evidence for the former existence of the Cretaceous peneplain. We have said that the most perfect development of the peneplain was from central Pennsylvania to Virginia, and it is just here where we should expect to find the best remnants of that old surface. In this region the typical Appalachian ridges and valleys, which run parallel to the trend of the mountain range, are very well developed. These valleys are the trenches cut along the belts of soft rock and to below the surface of the upraised peneplain, while the ridges have developed along the belts of hard rock, and their summits actually represent portions of the old peneplain surface. These ridges all rise to the same general level for miles around, and, as viewed from the summit of any one of them, the concordant altitudes give rise to what is called the "even sky line" which is a most striking feature of the landscape. Plate 35 gives an excellent idea of the even sky line across these ridges.

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[1] N. Y. State Mus. Bul. 146, p. 67.

In New York State the concordant altitudes are not so well shown both because the peneplain was here not so perfectly developed and because the attitude of the strata has largely been unfavorable to the formation of long, distinct ridges. Remnants of the peneplain are, however, unmistakably present in New York as, for example, on a very large scale over the great Southwestern plateau whose high points nearly always rise to altitudes of about 2000 feet. This plateau is simply a part of the upraised and dissected Cretaceous peneplain, and the slight downward sag toward the middle (already noted in chapter 2) is no doubt due to a slight downwarping of the general level during the process of uplift. The topographic map (plate 4) well illustrates the character of this dissected plateau. The present elevation of the peneplain remnants does not necessarily indicate the maximum amount of uplift. In the next chapter evidence will be presented to show that, for the New York area at least, the land was considerably higher in the Tertiary period than it is at present.

The summit of the Tug Hill province is a small plateau at an altitude of about 2000 feet, and it is merely a remnant of the upraised peneplain which was formerly connected with the Southwestern plateau. As one stands at the summit of Tug hill and looks out over the western slope of the Adirondacks, he is impressed by the remarkably even sky line there shown at an altitude of a little over 2000 feet. The east-central Adirondacks and the Catskills present exceptions because these regions stood out above the old peneplain.

The Mohawk and upper Hudson valleys have been so broadly and deeply trenched through soft strata that in them no remnants of the peneplain surface remain. Immediately eastward in the Berkshires, however, the old surface is well exhibited. In the Highlands-of-the-Hudson, a view from one of the high points shows a rather even sky line at an altitude of from 1200 to 1500 feet, the somewhat lower elevation of the old surface here being due to the fact that this region was east of the main axis of uplift.

Since the actual work of erosion or dissection of the upraised peneplain occurred during the Cenozoic era, further discussion of the subject is reserved for the next chapter· It has been the present purpose to prove that the Cretaceous peneplain actually existed and that it was upraised.

FAULTING OF THE EASTERN ADIRONDACKS

The eastern and southern Adirondack regions have been extensively fractured or faulted (see figures 23 and 24). In fact the major topographic features of those regions such as the numerous north-northeast by south-southwest ridges and valleys are largely dependent upon this faulted structure. These fractures are all of the normal fault type with fault surfaces practically vertical. Examination of the topographic maps of the whole eastern and southern Adirondacks shows that by far most of the ridges and valleys, streams and lakes trend in a north-northeast by south-southwest direction, or perfectly parallel to the direction of the major faults. Up to the present, no single fault has been proved to extend across the entire region, but rather there is a series of numerous parallel faults, no one of which has been traced much over 20 or 30 miles. The exact amount of displacement along these lines of fracture in the ancient crystalline rocks can not be determined, but in some cases it amounts to at least 2000 feet.

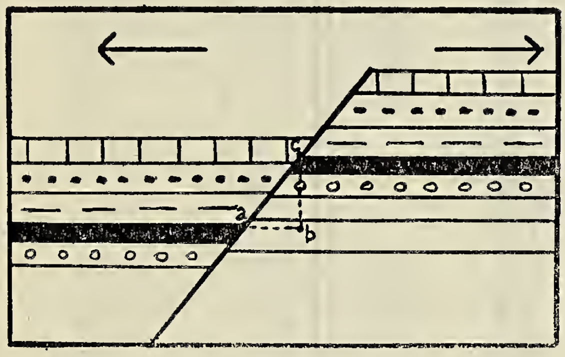

FIG. 23 Cross-section of a normal fault.

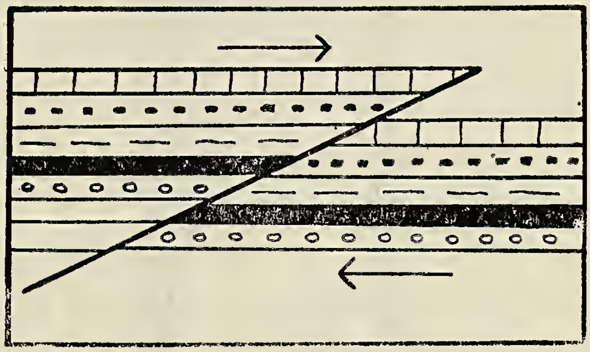

FIG. 24 Cross-section of a reversed or thrust fault.

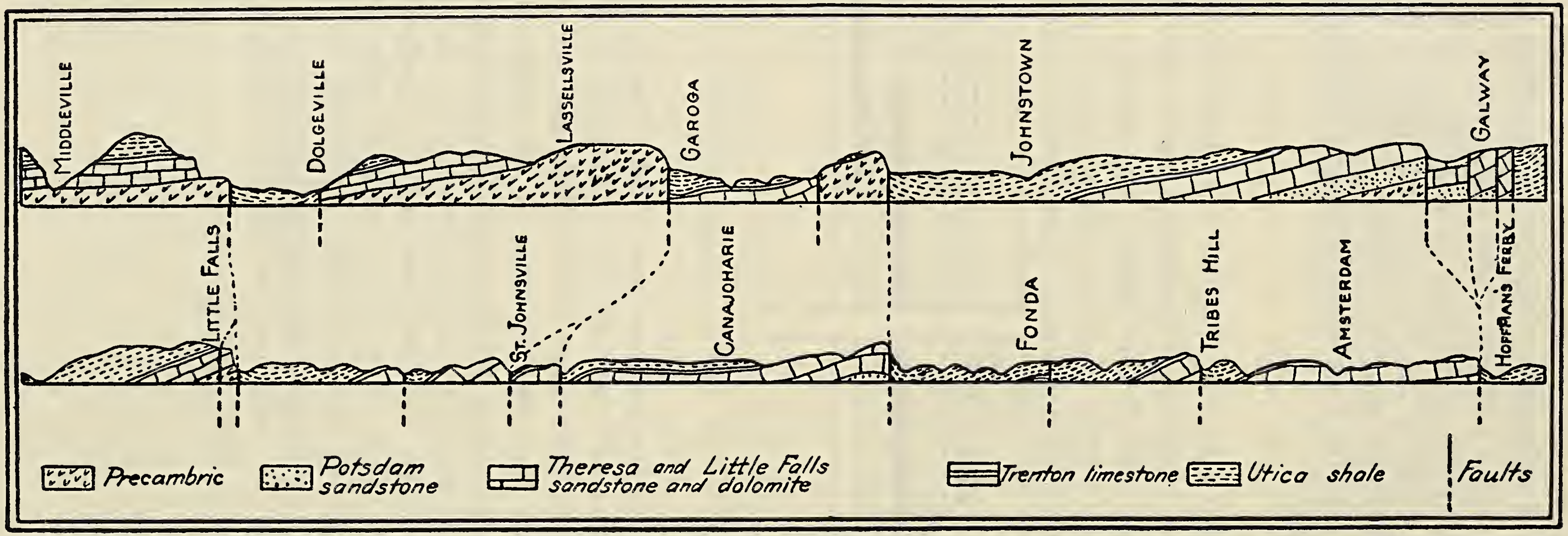

FIG. 25 Cross-sections of Mohawk valley faults. Lower section along the Mohawk river; upper section along a zone from 8 to 10 miles farther north. Length of each section 52 miles; vertical scale greatly exaggerated.

Modified after Darton, Annual Rep't N. Y. State Geol., 1894

This series of faults cuts through the early Paleozoic strata along the shores of Lake Champlain and in the Mohawk valley, and in these regions, due to marked differences in the rocks affected, it has been possible to determine carefully the character of the faults and the amounts of the displacements (see plate 37). Figure 25 shows two sections through the faulted region of the Mohawk valley.

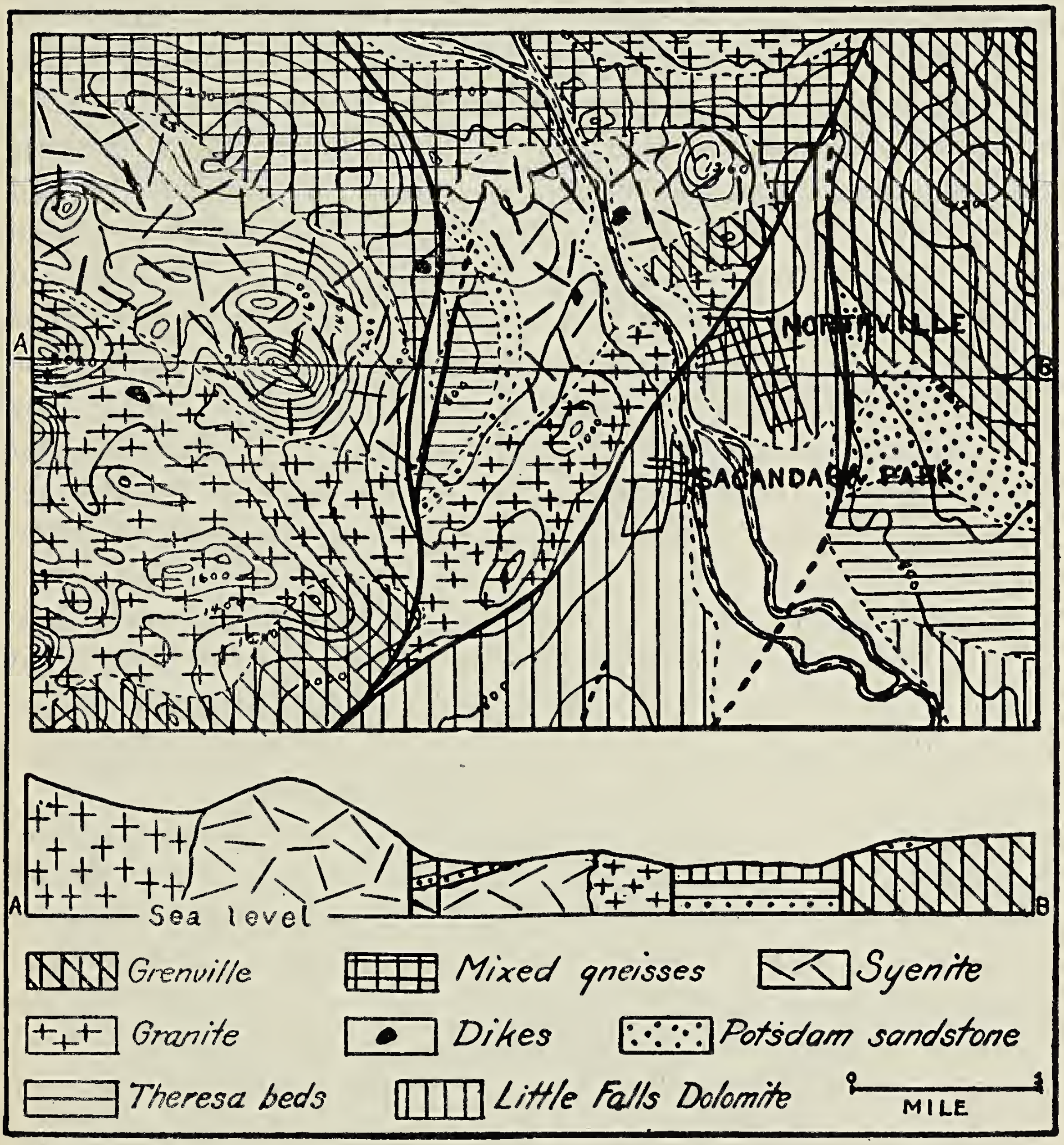

FIG. 26 Geologic and topographic map of the vicinity of Northville (Fulton county), showing an unusual variety of rock formations and structures along the southern border of the Adirondacks where the Precambrian and Paleozoic rocks come together, and where all have been greatly faulted. The position of the structure section is indicated by the line AB, the vertical scale of the section being twice exaggerated. The greatest fault is the one on the west, and the country immediately on the east side of it has dropped fully 1500 feet with respect to that on the west (mountain) side. Northville lies between two smaller faults on an earth block which has dropped several hundred feet with respect to the country on either side.

Geology by W. J. Miller, N. Y. State Mus. Bul. 153

To a considerable degree the topography of the valley is affected by the faults, especially where the harder Precambrian or Cambrian rocks form the scarp or upthrow sides of the faults. This is particularly true at Little Falls and the "Noses" (near Yosts) where, in each case, the Mohawk river has cut a gorge across a prominent fault scarp, and even down to the underlying Precambrian rock which has been brought relatively nearer the surface by the tilting of the earth blocks (see figure 7). On the geologic map of the State (figure 1) two tongues of Paleozoic rock are seen to extend northward well into the Precambrian rock area, and these are to be explained by the fact that, due to faulting along the west sides, the Paleozoic strata, for fifteen or twenty miles, have dropped down (relatively) fully 1500 feet with respect to the Precambrian rock. The much more resistant Precambrian rock has stood out against erosion and in each case it rises with steep front from 1000 to 1500 feet above the Paleozoic rock surface (see figure 26). The small remnant of Paleozoic strata already referred to as occurring at Wells in Hamilton county was dropped down fully 2000 feet by faulting against the Precambrian rock just west, and thus this remarkable Paleozoic outlier has been preserved from complete removal by erosion.

What is the age of the faulting or, in other words, when were these fractures developed? That some faulting, at least, occurred during Precambrian time has been well established but, so far as known, those faults are of very minor importance, and they have no appreciable influence upon the existing topography.

During the Paleozoic era, however, there is good reason to think that considerable faulting took place. At just what time during the era the faulting occurred is not now altogether certain, but it is certain that it was sometime after the deposition of the Odovician sediments because at many places those rocks are involved in the faulting. Cushing has suggested that the faulting may have been initiated at the time of the Taconic revolution when the rocks of the region immediately eastward were disturbed, but he says, "the great earth disturbances (Appalachian revolution) which prevailed in the Appalachian zone toward the close of the Paleozoic would seem more likely to have brought about the major faulting of the region."[1] At this latter time the rocks of northern New York were not folded but, as we have learned, the whole State was notably elevated, and during this disturbance conditions were cer-

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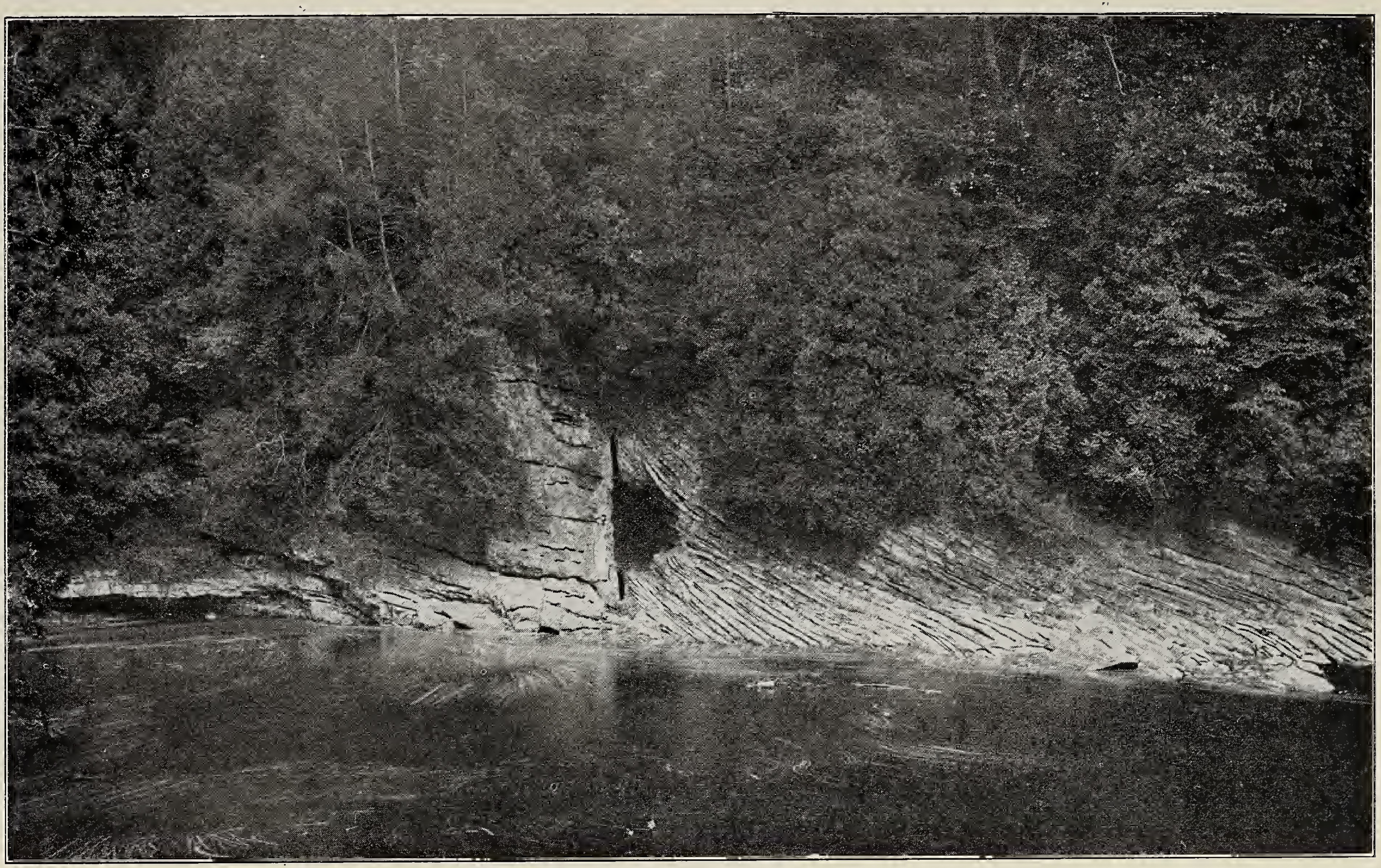
[1] N. Y. State Mus. Bul. 95, p. 405.

Plate 37



Normal fault in bank of East Canada creek near Manheim, Herkimer county. The heavy beds on the left are Little Falls dolomite and the thin beds on the right are Trenton limestone. The steep tilt of the Trenton strata was caused by friction producing a sort of up-drag effect, during the slipping of the rock masses. The hole is artificial.

From N. Y. State Geol. Rep't 1894, pl. 4, facing p. 4

tainly favorable for extensive fracturing of the strata. The disturbance of the early Mesozoic, which caused the fracturing of the Newark (Triassic) rocks along the Atlantic slope, quite certainly did not affect the Adirondacks because those faults are of a different type and closely confined to the Triassic basins.

If the major faulting occurred at the close of the Paleozoic, then the Mesozoic must have opened with the northeastern portion of the newly upraised New York State area cut by a great series of faults which caused the edges of the upturned earth blocks to stand out prominently as ridges. However this may have been, we are certain that by the close of the long period of Mesozoic erosion the old fault scarps or ridges were practically obliterated. If so, how do we account for the present Adirondack ridges which follow the fault lines? As a result of the uplift of the Cretaceous peneplain one or both of the following things happened, either there was renewed faulting, or that as a result of unequal erosion (due to differences in rock character) on opposite sides of the faults, the old fault scarps were renewed. It is quite certain that both things occurred, and thus the surface of the newly elevated Cretaceous peneplain in northeastern New York was made irregular by freshly formed fault scarps. This, together with the later (Cenozoic) erosion along the old fault lines and belts of weaker rocks, accounts for the existing Adirondack ridges. That some of the faulting actually dates from Cretaceous time, or possibly even later, is proved by the present existence of certain steep fault cliffs in perfectly homogeneous rock masses, and by the fault blocks which have been scarcely modified by erosion since their formation.

DRAINAGE OF NEW YORK IN THE MESOZOIC

Thus far we have said very little about the early drainage features of New York State. In fact we must admit that prior to the Cenozoic era, we have practically no knowledge concerning the positions of even the major drainage lines of the State. From our knowledge of the land and water relations during the Paleozoic era, we can form only the most general ideas regarding the drainage. The Mesozoic physiography of the State is better known and hence the drainage is perhaps better known, but even here positive knowledge is almost wholly lacking. The whole subject of the Precenozoic drainage of New York is one which demands thorough study before anything like satisfactory conclusions can be reached, and the following very brief discussion is intended to be merely suggestive of the problems involved.

At the close of the Paleozoic, and as a result of the Appalachian uplift, the region of New York State was raised well above sea level, with the greatest uplift toward the north as shown by the general south to southwesterly dip (tilt) of the Paleozoic strata (see figures 3 and 5). At that time those strata lapped over much of what is now the Precambrian rock area of the Adirondacks. The Appalachian folds of the Hudson valley region, as well as the highlands (of earlier origin) in general along the eastern border of the State, must have prevented any important eastward drainage. Thus, in the writer's belief, the strongest evidence suggests that the principal streams of the early Mesozoic era flowed in general southwesterly courses upon the surface of the newly upraised Paleozoic strata and away from the highlands of the eastern border of the State.[1]

If this be the correct interpretation (for others are certainly possible) of the early Mesozoic drainage, it must follow that no river at all comparable in length and position to the present Hudson could have existed along the eastern side of the State, and that no large rivers, like the Susquehanna and Delaware, then had southeasterly courses across the Appalachian mountains.

During the long Mesozoic era, the area of the State was profoundly eroded, as already proved. In the midst of this era the ruggedness of Mesozoic relief reached its maximum, and in accordance with well-known principles, the valleys must have formed along the belts of softer rock, while the harder rocks stood out to form the highlands or ridges. At this time the edges of the Paleozoic strata had sufficiently retreated (by erosion) on all sides from the central Adirondacks so that a considerable area of Precambrian rock had already become exposed in northern New York. During this retreat of the Paleozoic strata there was a tendency to form important valleys, especially along the western and southern borders of the Adirondacks, because whenever the harder rock formations were encountered they stood out as escarpments, while the softer rocks were worn down into valleys. It is in accordance with these principles that the Mohawk and Black river valleys were formed, though it does not necessarily follow that these older valleys occupied the same positions as the present ones because of the gradual retreat of these depressions away from the Adirondack region.

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[1] It should be stated that the Great Lakes were not then in existence, those bodies of water not having been formed till late in the Cenozoic era (see chapter 6).

In western New York and over the region of the present Lake Ontario, the hard and soft early Paleozoic strata outcropped along a nearly east and west direction, and hence considerable streams, tributary to the major southwestward flowing streams, doubtless followed the belts of soft (shale) rocks. Such a west-flowing stream may have followed the belt of weak Ordovician shales which runs under the present Lake Ontario.

In southeastern New York, in the midst of the Mesozoic era, the land was lower than at the beginning of the era as shown by the fact that the late Cretaceous sea spread over at least some of the region. This gave a better opportunity for the development of an eastward or southward drainage toward the Atlantic basin, and at this time it is possible that the ancestors of the modern Hudson, Delaware, and Susquehanna rivers were formed.

However uncertain our ideas may be regarding the topography and drainage of the early and middle Mesozoic, we are nevertheless sure that by the close of the period the topography of the State was that of mostly a peneplain which has already been described, and that the streams were all of low gradient and very sluggish. During the long erosion time of the Mesozoic, there must have been many changes in stream courses and adjustments to rock structures. By the close of the era the courses of the rivers are, as yet, not definitely known, though in accordance with the above discussion we are reasonably certain that the principal drainage of the State from the northern, central, and western portions was southwestward to westward into the Mississippi basin, while the drainage of the southeastern portion was southward to southeastward into the Atlantic basin.

Chapter 6

CENOZOIC HISTORY

TERTIARY PERIOD

Rock formations and life of the Tertiary. The Mesozoic closed and the Cenozoic opened with the uplift of the great Cretaceous peneplain. Before the uplift, the sea spread over the Long and Staten Islands region, but for a time after the uplift the land was there high enough to exclude the sea and New York State was wholly above sea level. This we know because the lowest (earliest) Tertiary deposits do not occur on Long or Staten Islands or in northern New Jersey, and hence the region must have been above water. The subdivisions of the Tertiary, from oldest to youngest, are known as Eocene, Oligocene, Miocene, and Pliocene. The early Eocene deposits are missing from the northern Atlantic Coastal plain, and on Long and Staten Islands we have no evidence that any of the Eocene or Oligocene is present which thus leads to the conclusion that all of southeastern New York was dry land during the whole of the Eocene and Oligocene. During the Miocene there was enough sinking to allow the sea to encroach over the Long and Staten Islands districts, as well as over the whole northern Coastal plain. Except for very slight oscillations of level which we shall here disregard, the region remained submerged under shallow sea water during the Miocene and Pliocene, that is till the close of the Tertiary period. The Tertiary deposits were sands, gravels, and clays which formed layer upon layer in the shallow sea along the margin of the continent (see figure 22), but on Long and Staten Islands they are seldom seen because of the more recent covering of glacial deposits. They are finely exposed in the Coastal plain of New Jersey.

The Tertiary period is generally called the "Age of Mammals" because, although mammals began in a small way in the Mesozoic, they became the dominant feature of life for the first time in the Tertiary. In the early Tertiary the mammals were very different in appearance from those of the present, a common form then being a generalized or ancestral type (for example, Phenacodus) about the size of a dog and having five toes. Many of our modern mammals have descended from this type. During the Tertiary the mammals developed very rapidly so that by the close of the period they were very much as they are today except that man, the highest and most wonderful animal of all, did not appear until the last (Quaternary) period of earth history. Birds developed to much like their present forms. Reptiles diminished both in size and number of species in a remarkable way, while fishes took on a decidedly modern aspect. The invertebrates of the Tertiary were not strikingly different from those of the present and by the close of the period they were so modern that from 75 to 90 per cent of them were the same species as those now living.

We have learned that, in the late Mesozoic, true flowering plants had been developed in abundance. During the Tertiary these and all other plants reached a development which in no essential way was different from that of the present.

The records of Tertiary life are but scantily represented in New York because of the small extent of exposed Tertiary rocks. In the deposits of the Atlantic Coastal plain, however, abundant fossils are found.

Development of relief features. The uplift of the great Cretaceous peneplain was an event of prime importance for New York because it literally furnishes us with the beginning of the history of most of the existing relief features of the State. Hence we assert with emphasis that all the principal topographic features of the State as we see them today date from the uplift of the Cretaceous peneplain because they have been produced by the dissection of that upraised surface. This dissection was largely the work of erosion, though in the eastern Adirondack region faulting has produced notable effects. All the great valleys such as the Champlain, St Lawrence, Black river, Mohawk, and Hudson have been produced since the uplift of the peneplain. It should also be stated that the Great Lakes, as well as the numerous lakes, gorges, and waterfalls for which New York is noted, were absent as geographic features at the opening of the Cenozoic.

As previously stated, the streams of New York which flowed upon the peneplain surface sluggishly meandered over deep alluvial or flood-plain deposits, and their courses were little if any determined by the character of the underlying rocks because hard and soft rocks alike were worn down to a general level. The uplift of the peneplain, however, greatly revived the activity of the streams so that they became very effective agents of erosion; they first cut channels through the alluvial deposits and then into the underlying bed rock. Thus these large original streams had their courses determined in the overlying deposits, and when the underlying rocks were reached the same courses had to be pursued entirely without reference to the underlying rock character and structures. Such streams are said to be superimposed because they have, so to speak, been let down upon the underlying rock masses. To quote Professor Berkey: "The larger rivers, the great master streams, of the superimposed drainage system, in some cases were so efficient in the corrasion of their channels that the discovery of discordant structures (in the underlying rocks) has not been of sufficient influence to displace them, or reverse them, or even to shift them very far from their original direct course to the sea. They cut directly across mountain ridges because they flowed over the plain out of which these ridges have been carved and because their own erosive and transporting power have exceeded those of any of their tributaries or neighbors."[1] Fine examples of such superimposed streams which are now entirely out of harmony with the structure of the regions over which they flow are the Susquehanna, Delaware, and Hudson. Thus the Susquehanna cuts across a whole succession of Appalachian ridges while, in accordance with the same explanation, the Delaware cuts through the Kittatinny range at the famous Delaware Water Gap. The lower Hudson pursues a course no less out of harmony with the structure of the country through which it passes. Thus it flows at a considerable angle across the Taconic folds above the Highlands, after which it passes through a deep gorge which it has cut through the hard granites and other rocks of the Highlands. The simple explanation is that the Hudson had its course determined upon the surface of the upraised Cretaceous peneplain, and that it has been able to keep that course in spite of the discordant structures of the underlying rocks.

But while the great master streams were thus cutting deep trenches in hard and soft rock alike, numerous side streams or tributaries came into existence and naturally developed along the belts of weak rocks and in harmony with the geologic structures. This is true of all the streams now occupying the valleys between the Appalachian ridges. In southeastern New York two remarkable cases are presented by the Wallkill river and Rondout creek which flow many miles northeastwardly and in a direction almost the reverse of that of the Hudson to which they are tributary. As the master superimposed Hudson cut its channel deeper and deeper, the Wallkill and Rondout side streams were enabled to cut their valleys deeper and deeper while they increased in length by pushing their headwaters farther southward, but only along belts of weak rock and in harmony with the northeast-southwest folded structure of the region.

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[1] N. Y. State Mus. Bul. 146, p. 69.

In a similar manner the great Mohawk valley has been developed. The Mohawk is the chief tributary of the Hudson, and whether or not its ancestor flowed in about the same position upon the surface of the peneplain, we do know that the present Mohawk valley (below Little Falls) has been carved out of the upraised peneplain by the Mohawk river and its tributaries along a belt of weak Ordovician shales. The valley is bounded on the north by the very hard Precambrian rocks and on the south by the fairly resistant limestones of the Helderberg escarpment. Proof is given on a succeeding page for the statement that late in the Tertiary (that is just prior to the great Ice age) the Mohawk river had its source near Little Falls, and that at the same time another stream (Rome river), now extinct, flowed westward from Little Falls, past Utica and Rome and into the basin now occupied by Lake Ontario. West Canada creek was then tributary to the Rome river, while the Sacandaga river flowed into the Mohawk instead of into the Hudson as it now does.

However uncertain we may be as to the location of a Precenozoic Susquehanna river, we are very certain that the present numerous, deep channels of the Susquehanna drainage system have been cut into the upraised peneplain. The Susquehanna, like the Hudson, is a good example of a superimposed stream and its ancestor may have flowed along the same general course over the low-lying peneplain before its uplift. Immediately after the uplift some of the more easterly headwaters of the Susquehanna came out of the southern Adirondacks. Evidences of this are as follows: (1) The present Mohawk valley had not been formed, the Mohawk river then having only begun the westward migration of its headwaters along the belt of soft shales; (2) the natural slope of the southern Adirondack region was then southward into the east branches of the upper Susquehanna; and (3) the positions of the present sources of the east branches of the Susquehanna at the crest of the high Helderberg escarpment, and in some cases within a very few miles of the present Mohawk river (see drainage map, figure 11) strongly argue for the cutting off or beheading of the former headwaters of the east branches. This beheading was accomplished by the Mohawk as its headwaters migrated slowly westward thus tapping one by one the upper waters of the east branches of the Susquehanna. Even today the Mohawk continues to steal drainage territory at the expense of the Susquehanna because the short, swift tributaries of the Mohawk, which flow northward over the Helderberg escarpment, are cutting down their channels rapidly, while their headwaters are migrating southward into the territory of the Susquehanna. A great network of large and small streams tributary to the upper Susquehanna drain a considerable portion of south-central New York, there being no single great master stream in this region because the rock formations are so nearly horizontal and are so much alike as regards resistance to erosion.

The Delaware system has had a history practically the same as that of the Susquehanna, except that it never drained any of the region north of the Mohawk.

The present ruggedness of the Catskills is largely, if not altogether, due to the production of deep channels which have been cut into the region, upraised at the time of the uplift of the great peneplain, by the headwaters of the Delaware, Schoharie creek (north-flowing), and the smaller streams flowing across the steep eastern front of the mountains.

During Tertiary times Lake Champlain was certainly not in existence, but the great depression was there, and it was no doubt largely developed or at least increased in depth, by the settling of earth blocks during the time of extensive faulting at the close of the Mesozoic, or the beginning of the Cenozoic. The depression is essentially a fault trough. The major stream occupying this valley flowed northward and in late Tertiary time, at least, the divide between the drainage of this and the Hudson valley passed between Glens Falls and Whitehall, and through the present position of the "Narrows" of Lake George, the lake, of course, not then being in existence.

Drainage of New York in the Tertiary. The outline of the probable drainage condition of western New York during the Mesozoic has already been given, and now as we attempt to restore the drainage conditions of the Tertiary, we must admit that some problems yet remain unsolved. Lakes Ontario and Erie certainly were not in existence. Streams flowed through these basins, which were not as deep as they now are. The bottom of Ontario is as much as 491 feet below sea level, and its surface lies at an altitude of 247 feet, and the altitude of Erie is 573 feet, and its greatest depth is 204 feet. The explanation of the increased depths of the basins is given beyond. The question now arises, did the waters from western New York drain westward or southwestward and into the Mississippi, or northeastward through the St Lawrence? According to J. W. Spencer, the St Lawrence received those waters, but in the light of what we have said about Mesozoic drainage, and also in view of the fact that the St Lawrence now, in the Thousand Islands region, does not flow through anything like a distinct channel (see plate 9) cut out by a great river, we must admit that there is little to favor such a view of northeastward drainage from western New York. The St Lawrence is almost certainly postglacial in its course at the Thousand Islands as shown by the lack of any real channel, and by the presence of a belt of hard Precambrian rock extending across the river, connecting the Adirondack with the Canadian Precambrian rocks. This hard rock belt must have formed a preglacial divide until the recent formation of Lake Ontario and the downwarping of the land which allowed the drainage to pass over the divide for the first time (discussed beyond).

Grabau's interpretation is that the Tertiary drainage of western New York passed westward and southwestward into the Mississippi, and this view is, in the writer's belief, far more tenable. The accompanying map (figure 27) gives a good idea of the drainage lines according to this view. The major drainage lines were no doubt inherited from the Mesozoic, the southwestward courses having been originally determined by the tilt of the land at the time of the Appalachian uplift. When the Cretaceous peneplain was upraised, these major streams as, for example, the Dundas river, again began very active work of erosion, and tributary streams were developed, during the Tertiary, along the belts of weak rocks. Thus an important west-flowing tributary was developed along the belt of soft Ordovician and Medina shales, and formed a valley where the basin of Lake Ontario now is. The Rome river, with source at Little Falls, became a branch of this stream while another important branch had its source on the Thousand Islands divide. There is also shown the position of the Black river which, by late Tertiary, had already carved out that important valley and flowed into the Ontario depression, according to Grabau. More recent evidence, however (see later page), strongly favors the passage of the lower end of the Black river north and northeastward into the precursor of the modern St Lawrence, and which had its source on the Thousand Islands divide.

On the accompanying map, the three south-flowing streams, one heading near Rochester, and the other two flowing through Lakes Seneca and Cayuga, are, in the writer's judgment, not properly shown for the late Tertiary, that is, just prior to the great Ice age. It is practically certain that preglacial streams were here north-flowing rather than south-flowing, because during long Tertiary time such tributaries to the large stream in the Ontario basin must have developed across the steep north slopes of the Niagara and Helderberg escarpments, and also because the slope of the Genesee river is now, at least, so decidedly downward toward the north. If the late Tertiary Genesee flowed southward, the reversal of its course must have been caused by a very marked tilting of the land, but we have no evidence for such a decided land movement.

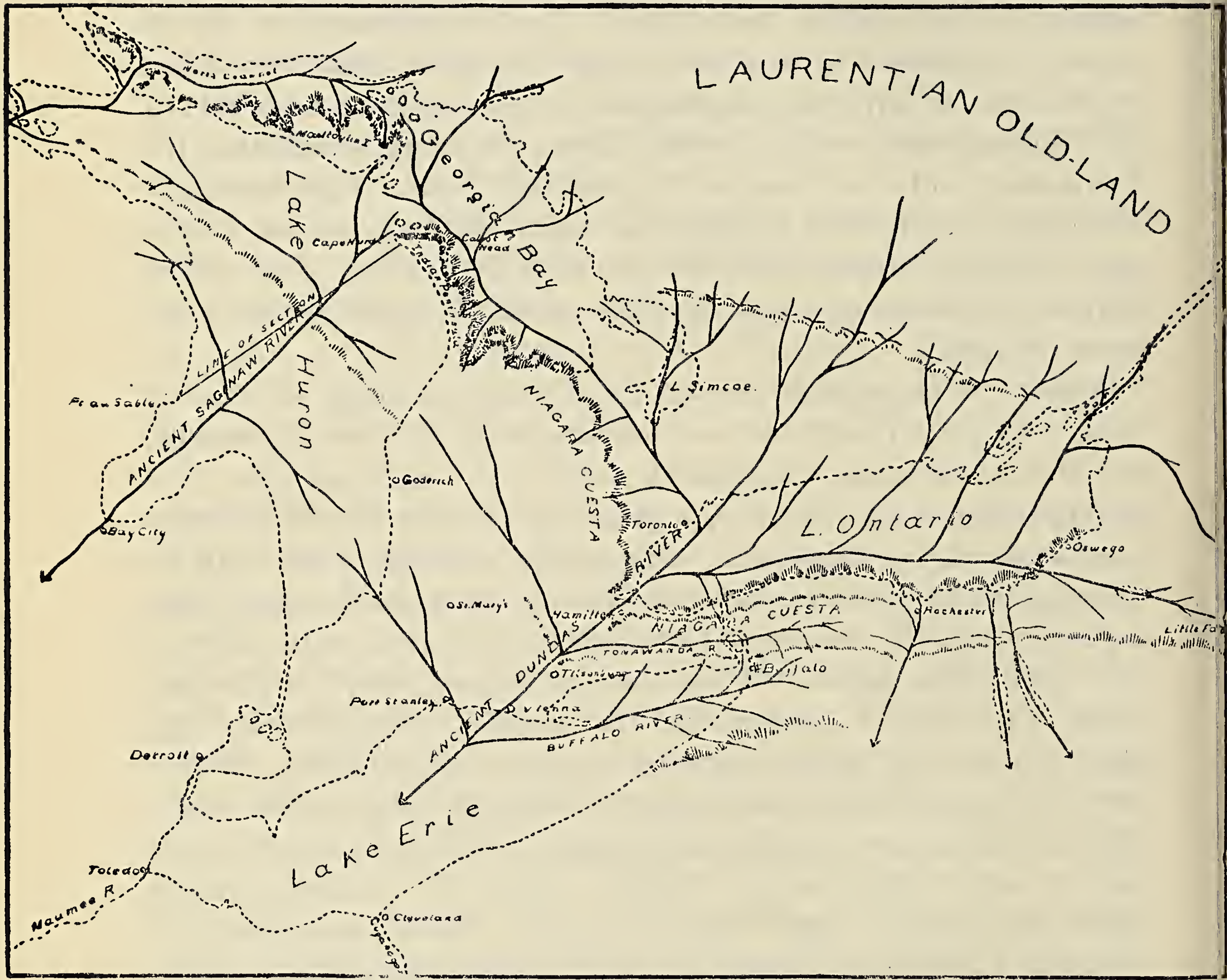
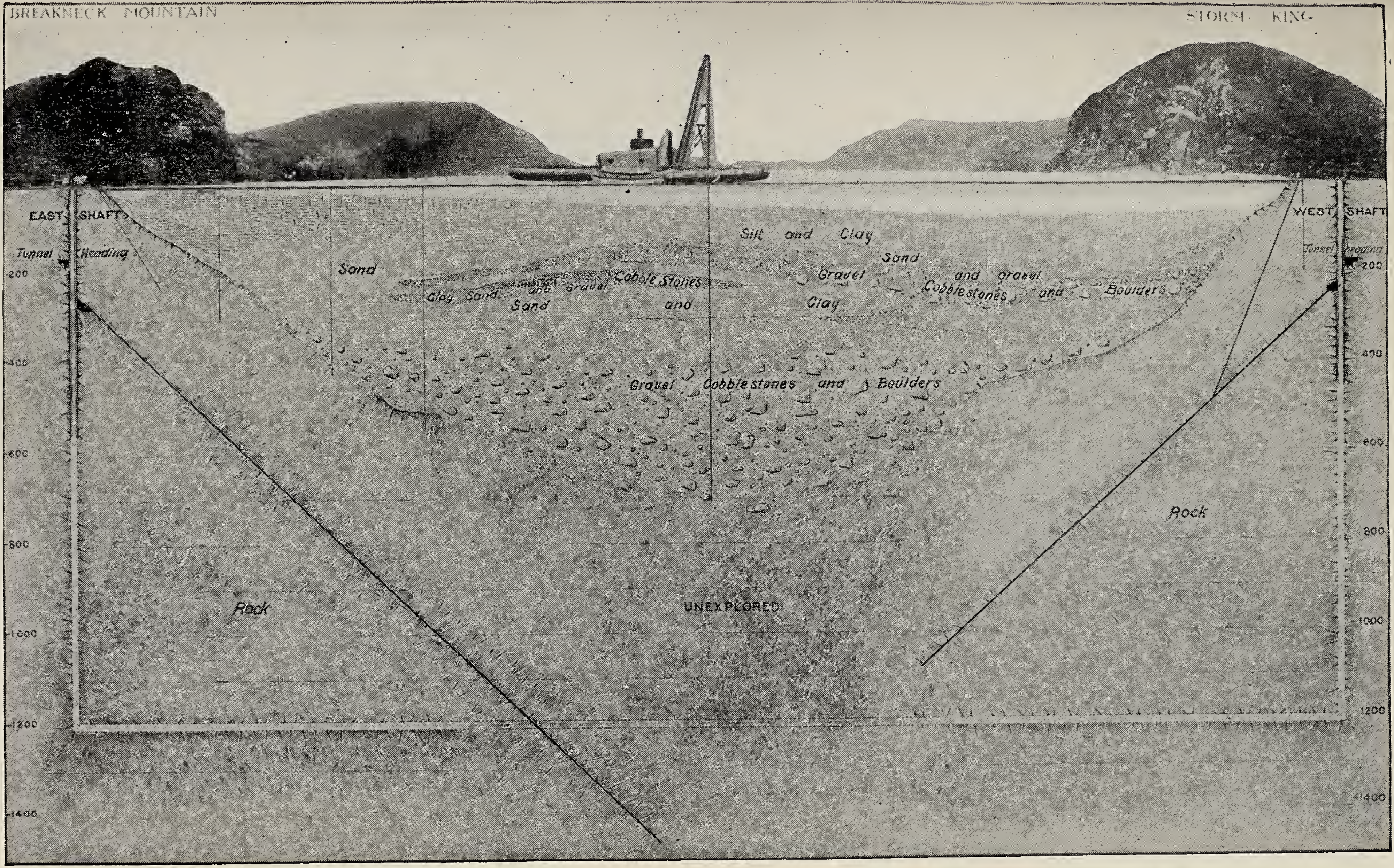


FIG. 27 Grabau's interpretation of late Tertiary drainage in the eastern Great Lakes region, the intention being to show the general kind of drainage rather than the exact location of the streams. The "Rome" river with source at Little Falls is well shown. The three south-flowing streams should, in the writer's opinion, be represented as north-flowing, at least immediately prior to the great Ice Age.

After Grabau, N. Y. State Mus. Bul. 45, fig. 6

Plate 30



A composite diagrammatic cross-section of the Hudson gorge at the entrance to the Highlands-of-the-Hudson between Storm King and Breakneck mountains. The shaft and tunnel (at a depth of 1200 feet) show the position of the New York City aqueduct. The bottom of the old Hudson channel is seen to be deeply buried under clay, sand, gravel and boulders. The center boring has penetrated more than 700 feet without striking the old rock bottom. The depth of the rock channel here is more than [illegible]000 feet or from the top of Storm King to the bottom of the buried channel.

From N. Y. State Mus. Bul. 146, pl. 14

In our discussion of Mesozoic drainage (see chapter 5) we found that, during the early part of that era, nearly all of the drainage of the state passed southwestward to westward into the Mississippi valley with very little if any, drainage into the Atlantic. But by the close of the Mesozoic, or the beginning of the Tertiary, a considerable south to southeastward drainage had been established along the lines of the Hudson, Susquehanna and Delaware rivers. Have we any explanation for the establishment of these important drainages into the Atlantic? One view is that the courses came about as a result of the meandering and changing of channels on the surface of the low-lying Cretaceous peneplain, and that these courses were maintained upon the upraised peneplain. Another view which the writer would suggest as worthy of consideration is that the south and southeasterly drainage lines were established as a result of the uplift of the peneplain. In chapter 5 it is shown that the axis of greatest uplift passed through northern New York from central Pennsylvania, and that the regions of southeastern New York and northern New Jersey were not raised so high. It is very reasonable, if not highly probable, that this very warping or slow arching up of the peneplain surface inaugurated the present drainage toward the Atlantic because the streams, no matter what their previous courses, then naturally must have flowed down that initial slope toward the Atlantic.

After the uplift of the peneplain the larger streams cut down their channels most rapidly and they were the first to reach "grade," that is, a condition in which, because of low velocity, they could no longer cut down their channels, though the widening process could continue because of side cutting due to meandering of the streams back and forth from one side to the other of the channels. The deep but broad-bottomed, stream-cut valleys so common in New York State show that many of the streams had reached a graded, or nearly graded, condition by the close of the Tertiary. In southeastern New York, at least, we have evidence to show that after the streams had reached grade there was an appreciable renewed uplift of the land which again revived the activity of the streams. Thus the broad Hudson valley, with minor hills rising above its surface, was produced when the Hudson was well along toward a graded condition, and then, as a result of this late Tertiary uplift of the land, the present narrow and fairly deep inner channel (gorge) of the Hudson was formed. The Hudson did not reach grade in this inner channel, its work having been interrupted by the spreading of the great ice sheet over the region. It is not known that this late Tertiary reelevation notably affected the rest of the State.

This inner gorge of the Hudson valley has been traced for fully 100 miles eastward beyond the mouth of the present river. The Coast and Geodetic Survey has made a detailed map (see figure 28) of the ocean bottom near New York City, and the submerged channel of the Hudson river is clearly shown as a distinct trench cut into the continental shelf. Even in the Hudson valley above New York City, the narrow inner rock channel has a depth of hundreds of feet (see plate 38), and it is mostly submerged below tide water. Without any question this submerged Hudson channel was cut when the region was dry land, and thus we have positive proof that late in the Tertiary, and possibly extending into the early Quaternary, the region of southeastern New York was notably

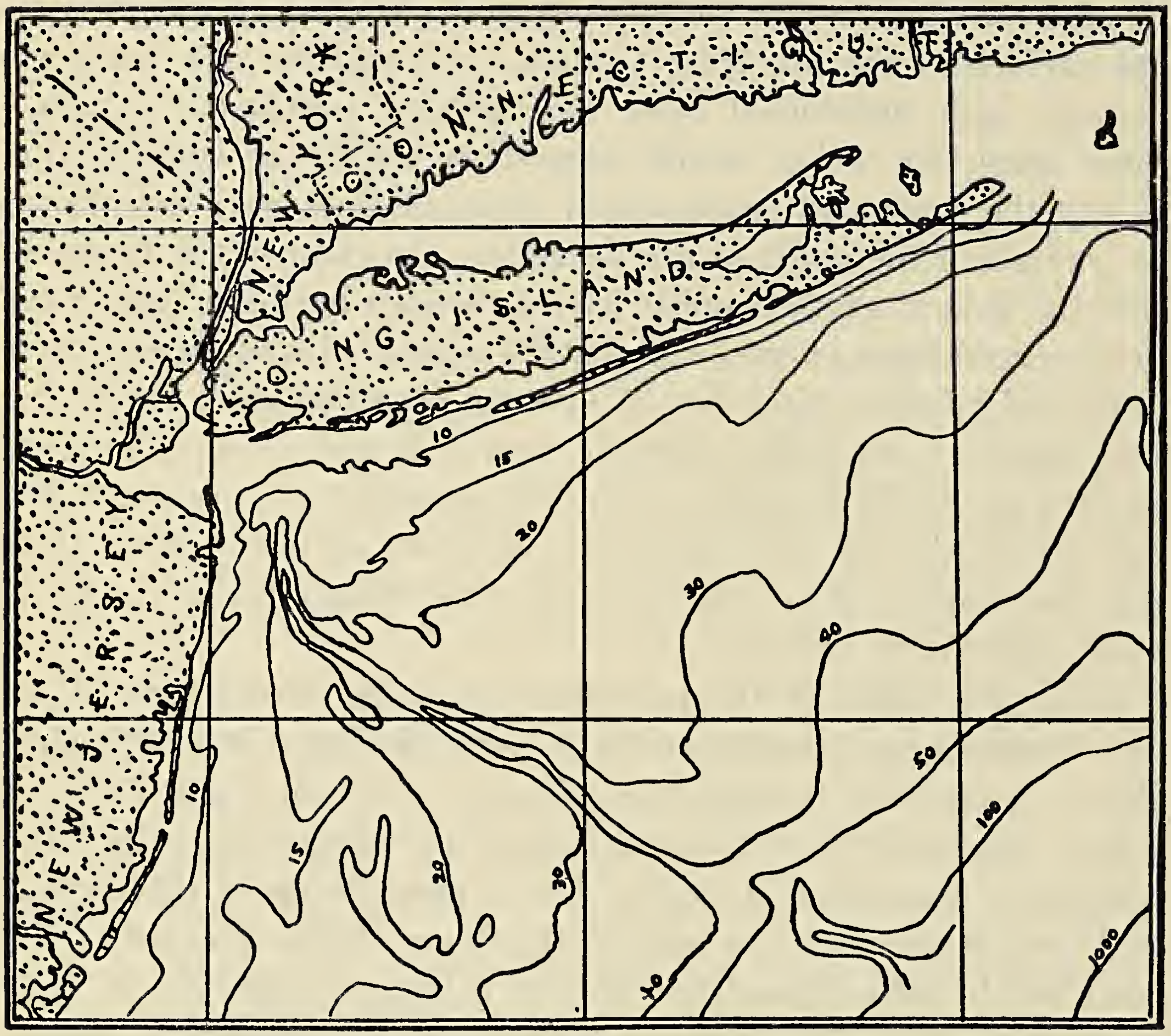
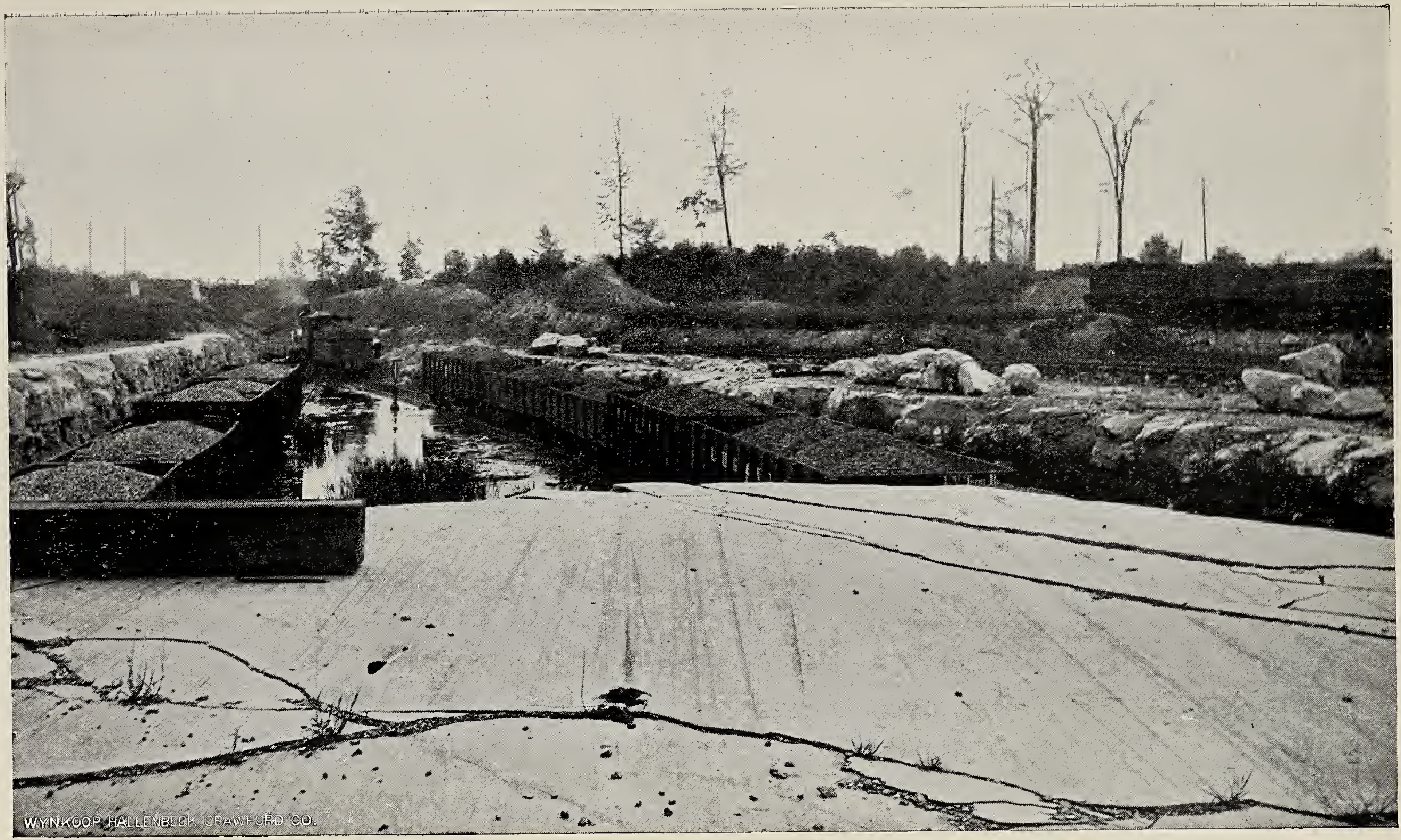


FIG. 28 The submerged Hudson River channel, whose position is clearly shown by the contour lines. Figures indicate depth of water in fathoms. Data from Coast and Geodetic Survey.

Plate 39



Glaciated surface of Onondaga (Devonian) limestone at Cheektowaga, Erie county. The passage of the great ice sheet over this ledge of rock wore it down to a generally smooth surface, except for the scratches which were produced by the abrasion of small rocks or pebbles at the bottom of the ice.

From N. Y. State Mus. Bul. 19, pl. 94

higher than it is today. Conservative estimates place the amount of elevation greater then than now at not less than 2000 feet because the very end of the Hudson channel is submerged to that extent.[1] The coast was then at what is now the edge of the continental shelf or platform about 100 miles east of the present coast line. That this greater altitude was before the Ice age is proved by the fact that the inner Hudson channel now contains much glacial debris filling. That all of New York State was then higher than now is quite certain because with the lower Hudson region considerably elevated, the upstate region must also have been elevated (though possibly not so much) in order to maintain the gradients of the actively eroding streams.

To summarize briefly the drainage and physiography of the State during the Tertiary, we may say that, with a certain few important exceptions, the major features as we see them today were practically the same towards the close of the Tertiary, and that these relief features were developed by erosion which began with the uplift of the great peneplain at the opening of this period or the close of the one just preceding. A few of the more notable differences between the drainage of the late Tertiary and the present are as follows: Very few, if any, lakes, waterfalls, or gorges existed; Lakes Erie and Ontario were absent and these basins contained important streams which appear to have drained westward into the Mississippi; the St Lawrence river probably had its source in the Thousand Islands region; the Mohawk river had its source on the divide at Little Falls, while the so-called Rome river flowed westward from Little Falls; West Canada creek entered the Rome river; the Sacandaga river entered the Mohawk; the State, especially the southeastern portion, was notably higher (perhaps not less than 2000 feet) than it now is so that the Atlantic coast line was about 100 miles farther out where the Hudson emptied into the ocean; and Long and Staten Islands did not then exist as such.

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[1] It has been suggested by Chamberlain and Salisbury (Geology, vol. 1, page 529) that the very end of the Hudson, and other submerged channels, may have been deepened by tidal scouring and, if so, the figure (2000 feet) generally given may be too high. At any rate the Hudson channel at the Highlands is submerged nearly 800 feet which certainly implies an altitude of more than 1000 feet greater than now when the river was actively eroding.

QUATERNARY PERIOD, INCLUDING NEW YORK IN THE GREAT ICE AGE

The fact of the Ice age. The Quaternary is the last great period of earth history, and it still continues for it has led up to the present-day conditions. This period was ushered in by the spreading of vast ice sheets over much of northern North America and Europe, and this takes rank as one of the most interesting and remarkable occurrences of geological time. On first thought the existence of such vast ice sheets seems unbelievable, but the Ice age occurred such a short time ago that the records of the event are perfectly clear and conclusive. The fact of this great Ice age was discovered by Louis Agassiz in 1837, and fully announced before the British Scientific Association in 1840. For some years the idea was opposed, especially by advocates of the so-called iceberg theory. Now, however, no important event of earth history is more firmly established and no student of the subject ever questions the fact of the Quaternary Ice age.

Some of the proofs of the former presence of the great ice sheet are as follows: (1) Polished and striated rock surfaces (see plate 39) which are precisely like those produced by existing glaciers, and which could not possibly have been produced by any other agency; (2) glacial boulders or "erratics" which are often somewhat rounded and scratched, and which have often been transported many miles from their parent rock ledges; (3) true glacial moraines, especially terminal moraines, like that which extends the full length of Long Island and there marks the southernmost limit of the great ice sheet; and (4) the generally widespread distribution over most of the glaciated area of heterogeneous glacial débris, both unstratified and stratified, which is clearly transported material, and, which rests typically upon the bed rock by sharp contact.

Ice extent and centers of accumulation. The best known existing great ice sheets are those of Greenland and Anarctica, especially the former which covers about 500,000 square miles. This glacier is so large and deep that only an occasional high rocky mountain projects above its surface, and the ice is known to be slowly moving outward in all directions from the interior to the margins of Greenland. Along the margins, where melting is more rapid, some land is exposed, but often the ice flows out into the ocean where it breaks off to form large icebergs.

The accompanying map (figure 29) shows the area of nearly 4,000,000 square miles of North America covered by ice at the time of maximum glaciation, and also the three great centers of accumulation and dispersal of the ice. The directions of flow of the ice from these centers have been determined by the study of the directions of a very large number of glacial striae or scratches.

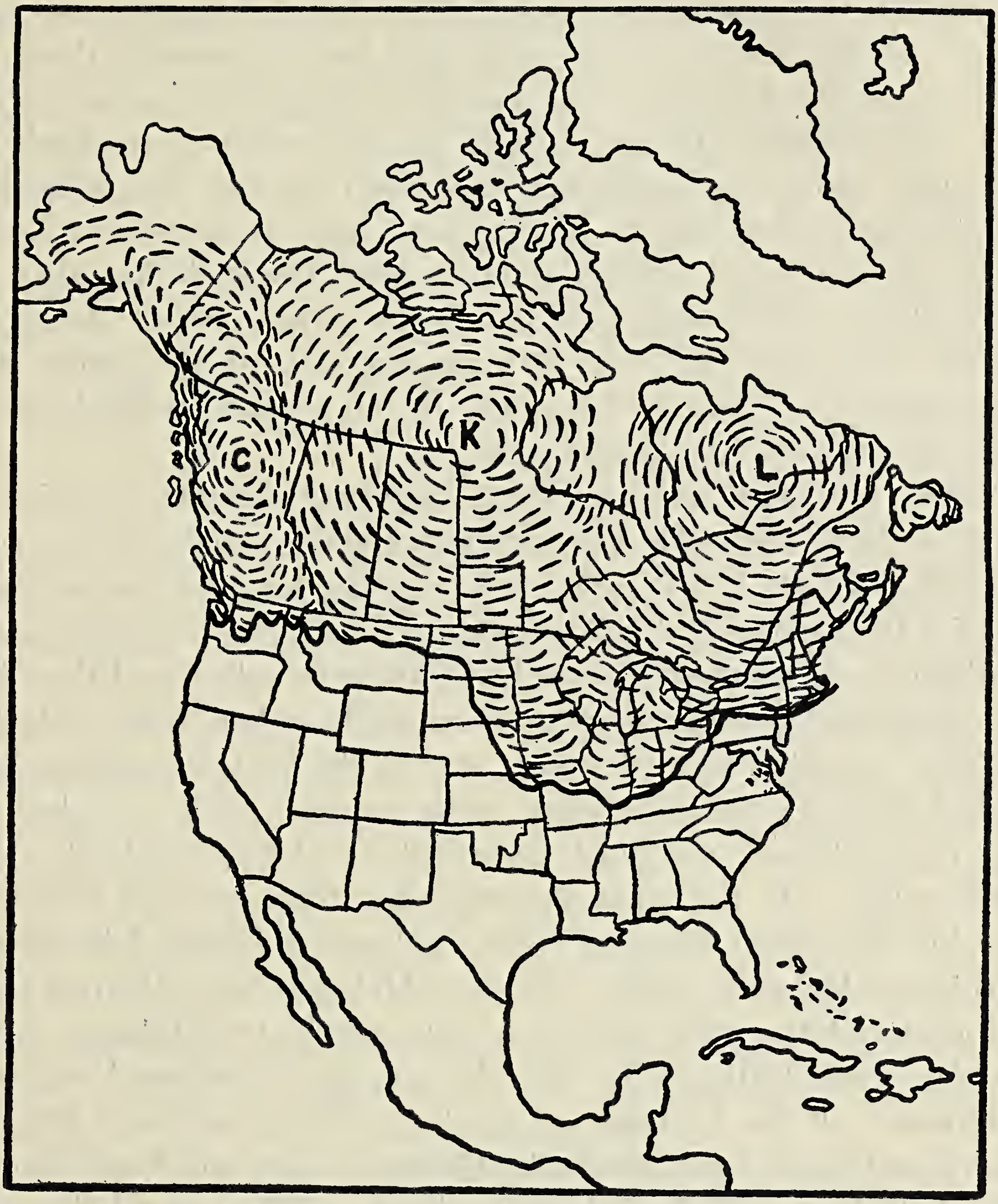


FIG. 29 Map of North America showing the maximum extent of the great ice sheets of the Quaternary period. The three great ice centers are shown by the letters as follows: L = Labrador or Laurentide Glacier; K = Keewatin Glacier; and C = Cordilleran Glacier. All of New York State, except probably the very southern border of Long Island and the southern part of Cattaraugus county, was buried under ice.

It was the Labradorean or Laurentide ice sheet which spread southward over New York to cover all the State except the southern border of Long Island, and a little of Cattaraugus county. It must of course be remembered that the North Atlantic coast line was then considerably farther out than now because of the greater elevation of the land.

Direction of movement and depth of ice in New York. The fact that glacial ice flows as though it were a viscous substance is well known from studies of present-day glaciers in the Alps, Alaska, and Greenland. A common assumption, that either the land at the center of accumulation must have been thousands of feet higher, or that the ice there must have been immensely thick, in order to permit flowage so far out from the center, is not necessary. For instance, if one proceeds to pour viscous tar slowly in one place upon a perfectly smooth (level) surface, the substance will gradually flow out in all directions, and at no time will the tar at the center of accumulation be very much thicker than at other places. The movement of the ice from one of the great centers was much like this, only in the case of the glacier the accumulation of snow and ice was by no means confined to the immediate centers of accumulation.

When the Labradorean ice sheet spread out southward as far as northern New York, the Adirondack mountains stood out as a considerable obstacle in the path of the moving ice, and the tendency was for the current to divide into two portions, one of which passed southwestward up the low, broad St Lawrence valley, and the other due southward through the deep, narrow Champlain valley. As the ice kept crowding from the rear, part of the St Lawrence ice lobe pushed into the Ontario basin, while another portion pushed its way up the broad, low Black river valley and finally into the Mohawk valley. At the same time the Champlain ice lobe found its way into the upper Hudson valley, and sent a branch lobe up the broad, low Mohawk valley. The two Mohawk lobes, the one from the west and the other from the east, met in the Mohawk valley not far from Little Falls. As the ice sheet continued to push southward, all the lowlands of northern New York were filled, a tongue or lobe was sent down the Hudson valley, and finally almost the whole State was buried under the ice. The general direction of ice movement at this time of greatest ice extent was southward to southwestward with perhaps some undercurrents determined by the larger topographic features. Thus we learn that the major relief features of the State very largely determined the direction of ice currents, except at the time of maximum glaciation when only the undercurrents were controlled.

These ideas are abundantly borne out by the character and distribution of the glacial striae and boulders over the State. Central New York is literally strewn with thousands of glacial boulders or erratics which were transported from the Adirondacks by the ice, and similar boulders are occasionally found as far south as Binghamton, and well down the Hudson valley. Evidences of glaciation also occur high up in the Adirondacks and the Catskills, and, therefore, the greatest depth of ice over New York State could not have been less than several thousand feet. In fact, we have every reason to believe that the Adirondacks, if not the Catskills, were completely buried. The reader may wonder how an ice sheet a mile thick in northern New York could have thinned out to disappearance at or near the southern border of the State, but observations on existing glaciers show that it is quite the habit of extensive ice bodies to thin out very rapidly near the margins, thus producing steep slopes along the ice fronts.

Successive ice invasions. The front of the great ice sheet, like that of ordinary valley glaciers, must have shown many advances and retreats. In the northern Mississippi valley, however, we have positive proof for several (perhaps five or six) important advances and retreats of the ice which gave rise to true interglacial stages. The strongest evidence is the presence of successive layers of glacial débris, a given layer often having been oxidized, eroded, and covered with vegetation before the next (overlying) layer was deposited. In drilling wells through the glacial deposits of Iowa, for example, two distinct deposits or layers of vegetation are often encountered at depths of from 100 to 200 feet. Near Toronto, Canada, plants which actually belong much farther south in a warmer climate have been found between two layers of glacial débris. Thus we know that some, at least, of the ice retreats produced interglacial stages with warmer climate and that they were sufficient greatly to reduce the size of the continental ice sheet, or possibly to cause its entire disappearance.

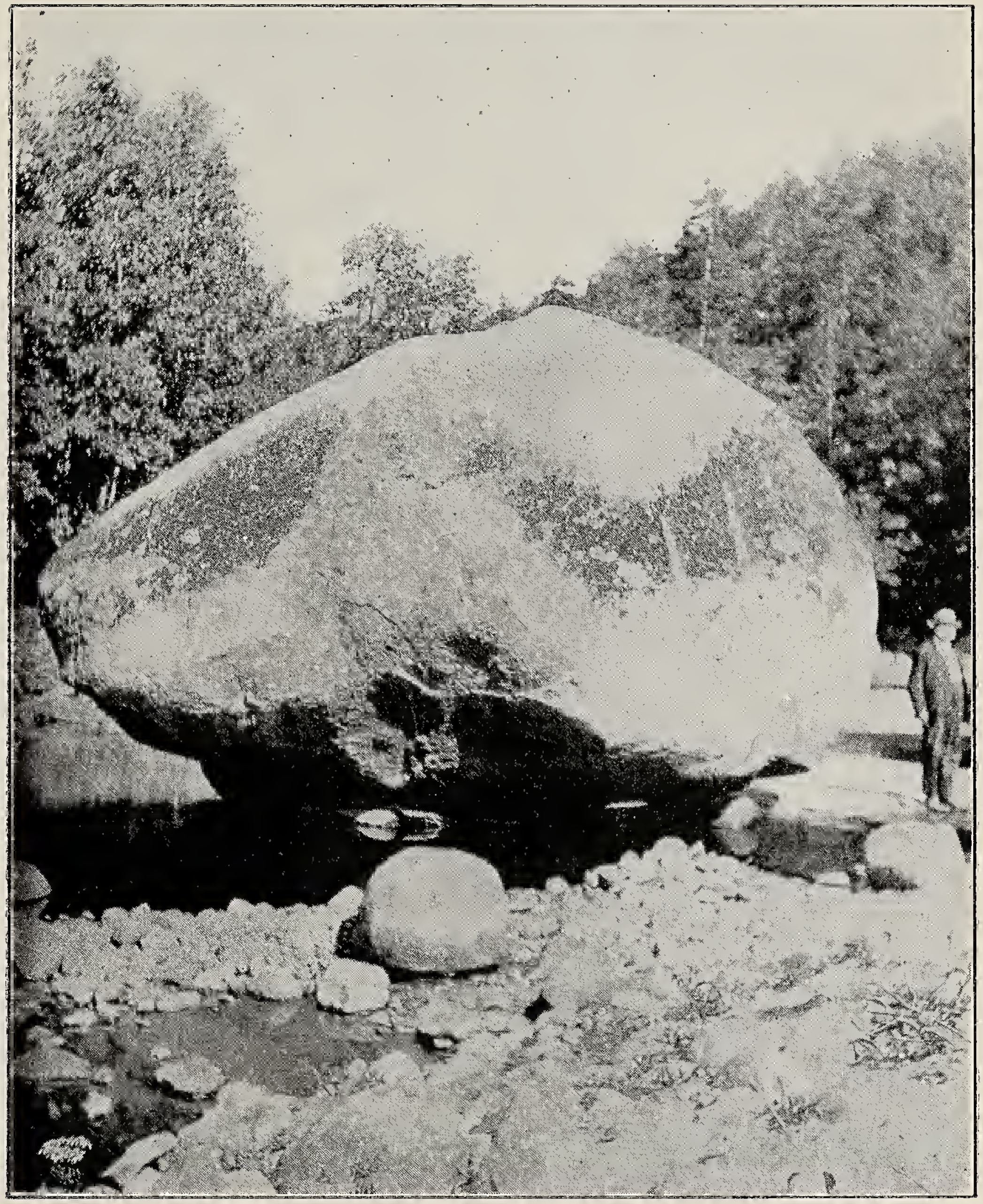
In New York State no very positive evidence has as yet been found to prove truly multiple glaciation, though some phenomena as, for example, certain buried gorges, are very difficult to account for except on the basis of more than one advance and retreat of the ice. At any rate, there appears to be no good reason whatever to believe that there were more than two advances and retreats of the ice over the State. For our purpose in considering only the general effects of glaciation we may practically disregard the problem of multiple glaciation because the final effects would have been essentially the same as a result of a single great glacial advance and retreat.

Ice erosion. Ice, like flowing water, has very little erosive effect upon rocks unless it is properly supplied with tools. When flowing ice is shod with hard rock fragments the power to erode is often pronounced because the work of abrasion is mostly accomplished by the rock fragments rather than by the soft ice itself. For instance, when the great ice lobe moved up the St Lawrence valley it was shod with many pieces of hard Precambrian rocks, and the effects of erosion are remarkably well shown in the Thousand Islands region. Thus, about two miles due south of Clayton the writer has seen a succession of great grooves, covering an area of several acres, and cut into the hard, fresh Potsdam sandstone on top of a low hill. A little search will reveal polished and scratched or grooved rock surfaces in almost any part of the State. Granite ledges in the Adirondacks are often glaciated, and the freshness and hardness of the surface rock proves that the ice eroded all the deep preglacial soil as well as the zone of rotten rock, and an unknown amount of live or fresh rock.

In former years a very great erosive power was ascribed to flowing ice, but today some glacialists consider ice erosion to be almost negligible, while many others maintain that, under favorable conditions, flowing ice has a very considerable erosive effect. During the very long preglacial time, rock decomposition must have progressed so far that rotten rock, including soils, had accumulated to considerable depths, as today in the southern states. Such soils are called "residual" because they are derived by the decomposition of the very rocks on which they rest. But now one rarely ever sees rotten rock or soil in its original place in New York because such materials were nearly all scoured off by the passage of the great ice sheet, mixed with other soils and ground up rock fragments and deposited elsewhere. Such are called transported soils. Along the southern side of the State, where the erosive power of the ice was least, rotten rock is not so uncommonly seen.

Ice, shod with hard rock fragments and flowing through a deep, comparatively narrow valley of soft rock, is especially powerful as an erosive agent because the abrasive tools are supplied; the work to be done is easy; and the increased depth of the ice where crowded into a deep, narrow valley causes greater pressure on the bottom and sides of the valley. Many of the valleys of northern New York were thus very favorably situated for ice erosion, as for examples, the Champlain, St Lawrence, Black river, and Finger lakes valleys, as well as many of the nearly north-south valleys of

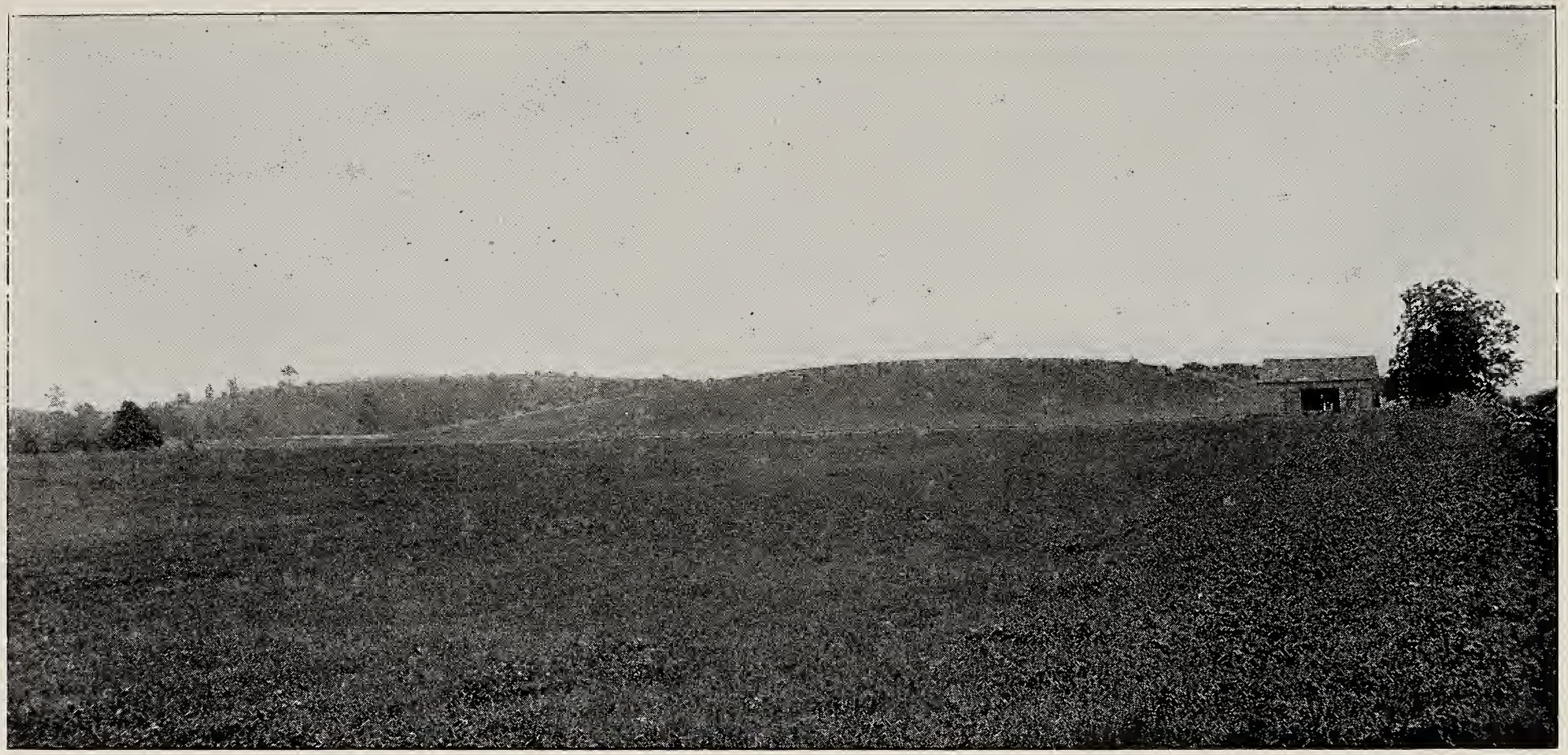
Plate 40



A glacial boulder or "erratic" of Precambrian syenite in the bed of Black river, 2 miles northeast of Boonville, Oneida county. The boulder is 27 feet across and 17 feet high and rests upon Black River limestone. It has been transported some miles at least.

Photo by W. J. Miller

Plate 41



Drumlins in Wayne county, 3 miles north of Walworth. Looking east of south.

From N. Y. State Mus. Bul. 111, pl. 25

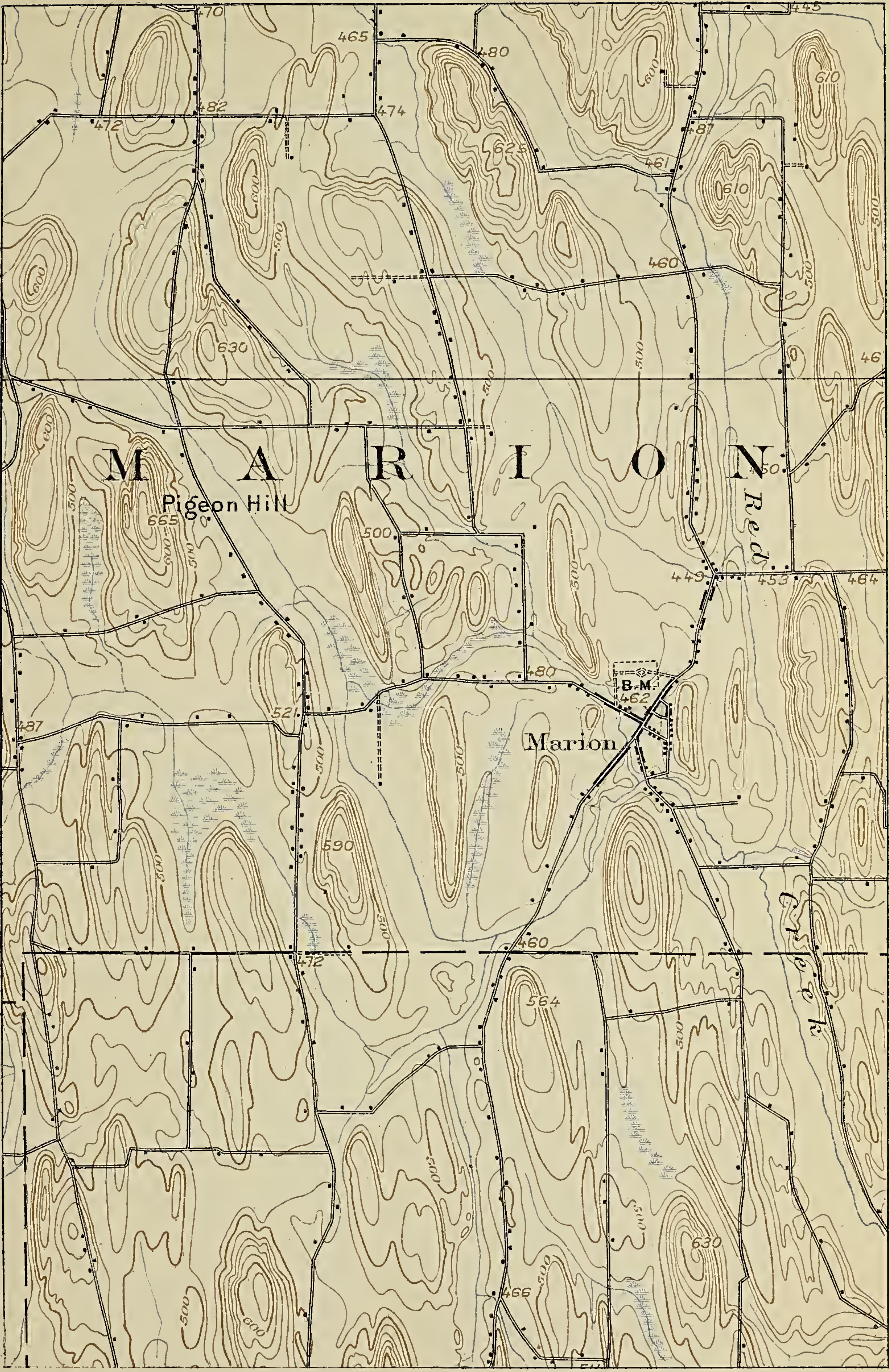
the Adirondacks. The writer has made a special study of ice erosion in the Black river valley. Figure 35 is a structure section across the valley showing the rock terraces and the relations of the various rock formations. The high, steep, terrace fronts are certainly young topographic features which could not have been present at the close of the long preglacial erosion period, nor could they have been formed since the Ice age because glacial deposits, even near the valley bottom, have not yet been removed. There is still the possibility that glacial waters may have done the work, but there is no evidence for such vigorous water action especially on the higher part of the Trenton limestone terrace where records would surely be left. On the contrary, there are glaciated rock surfaces and also glacial deposits (kames) on the great limestone terrace and near the base of the steep front of the shale terrace, so that the work could not have been done by glacial waters before the ice retreat. Evidently, we have here a fine example of ice erosion, and before the Ice age the limestones and shales extended somewhat farther eastward than they now do. The conditions for ice erosion were here unusually favorable because the ice, in its great sweep around the Adirondacks, was shod with many fragments of very hard rocks when it entered the deep Black river valley, striking with greatest force against the soft sedimentary rocks of the west side of the valley. As the figure clearly shows, the very soft shales were worn back more than the harder limestones, while the very hard Precambrian rocks were very little affected. This is perhaps the best example of ice erosion in northern New York, but even here we must admit that only soft rocks were much eroded and that the great preglacial Black river valley was comparatively little modified. If soft shales had made up the valley bottom, ice erosion would have caused considerable deepening as was, no doubt, the case in the valleys of the Finger lakes region.

Most of the Adirondack mountain peaks, especially the more isolated ones, were thoroughly scraped off and rounded down to the very live or fresh rock (see upper view, plate 17), while the favorably situated valleys were vigorously glaciated by the removal of all the rotten rock and at least some of the fresh rock, especially when the latter was the comparatively soft Grenville limestone. Such phenomena are particularly well exhibited in Warren county (see figure 13) where the landscape is characterized by many great, glaciated rock domes which rise above the valleys of weak Grenville. In a few cases where the ice moved directly across deep valleys, like that between Lake George village and Warrensburg, the rotten rock to great depth may still be seen in its original place.

In conclusion we may say that while many comparatively small, local features were produced by ice erosion, the major topographic features of the State were practically unaffected by ice erosion during the passage of the great ice sheet.

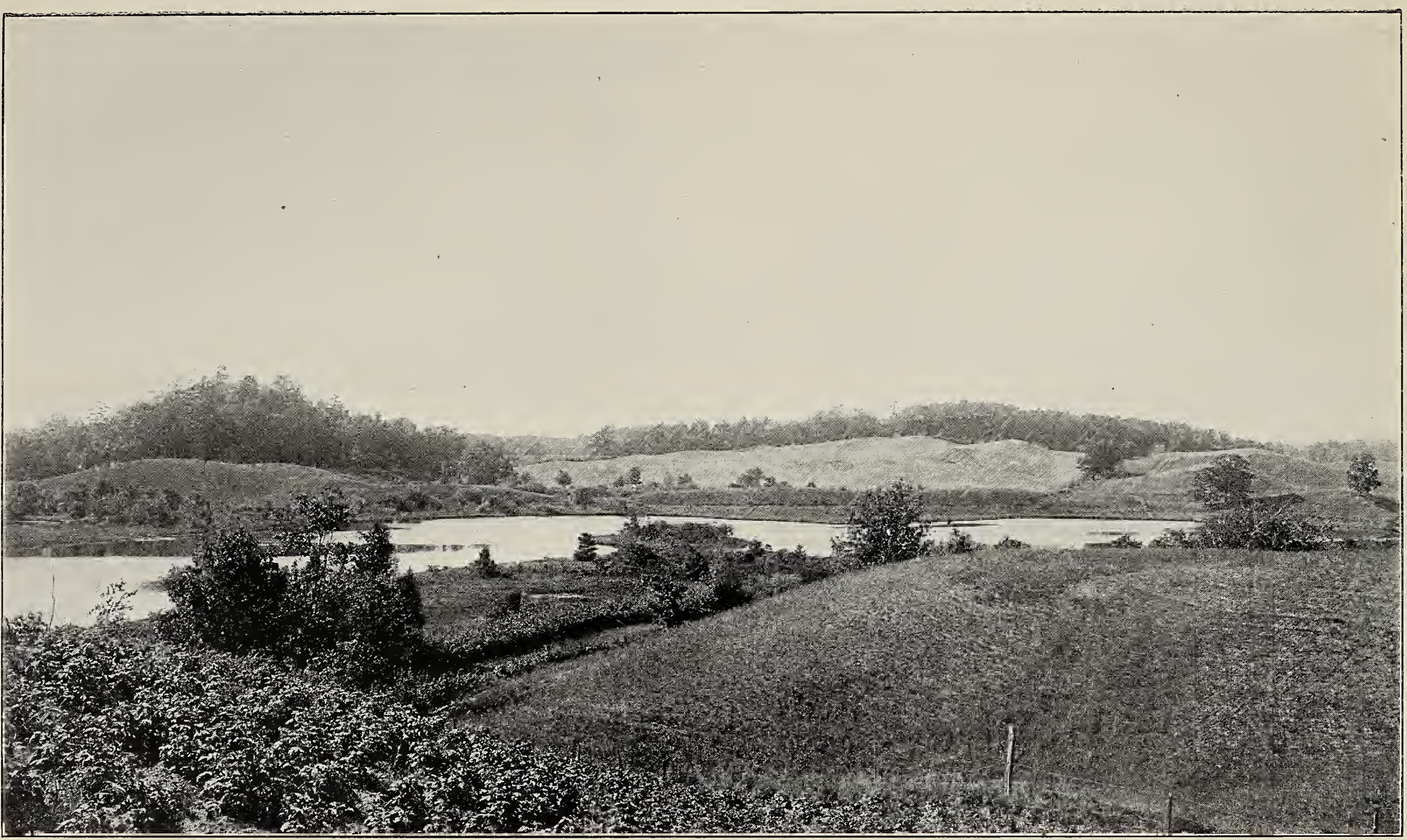
Ice deposits. The vast amount of débris transported by the great ice sheet was carried either on its surface, or frozen within it, or pushed along under it. It was very heterogeneous material ranging from the finest clay through sand and gravel, to boulders of many tons weight. The deposition of these materials, as we now see them, took place during both the advance and retreat of the ice, but chiefly during its retreat. Most of the deposits made during the ice advance were obliterated by ice erosion, but those formed during the ice retreat have been left intact except for the small amount of postglacial erosion. The general term applied to all deposits of glacial origin is "drift," this term having been given at the time when they were regarded as flood deposits. Drift deposits cover practically all of New York State except where bare rock is actually exposed, and its thickness is very variable, ranging from nothing to several hundred feet.

The ice sheet could advance only when the rate of motion was greater than the rate of melting of the ice front and vice versa in the case of retreat. Thus it is true, though seemingly paradoxical, to assert that the ice was constantly flowing southward even while the ice front was retreating northward. Whenever, during the great general retreat, the ice front remained stationary because the forward motion of the ice was just counterbalanced by the melting, all the ice reaching the margin of the glacier dropped its load to build up a *terminal moraine.* Such a moraine is a more or less distinct range of low hills and depressions consisting of very heterogeneous and generally unstratified débris, though at times waters emerging from the ice caused stratification. The depressions are usually called *kettle holes.* The so-called great terminal moraine marks the southernmost limit of the ice sheet, and it is wonderfully well shown by the ridge of low irregular hills extending the whole length of Long Island (see plate 12). It is also clearly traceable across northern New Jersey and Pennsylvania and it passes through southern Cattaraugus county in New York. Terminal moraines farther northward are generally not so long nor sharply defined, the one of perhaps most prominence having



A topographic map illustrating that part of the Ontario plain which is studded with low, elliptical-shaped hills (drumlins) of glacial origin. Practically every hill seen from the train window between Syracuse and Rochester is a drumlin. From the Palmyra (U. S. G. S.) quadrangle. Scale, about 1 mile to the inch.

Plate 43



Typical glacial topography as seen near West Junius, Ontario county. The low, irregular hills all consist of stratified glacial débris and are known as "kames."

From Annual Rep't N. Y. State Geol., 1894, pl. 8, facing p. 80

been traced from Herkimer through Oriskany Falls, Cortland, Watkins, Bath, Portageville, Dayton, and Jamestown. Moraines, either terminal or lateral, are often locally very prominently developed.

When the ice front paused for a considerable time upon a rather flat surface, the débris-laden streams emerging from the ice formed what is called an *overwash plain* by depositing layers of sediment over the flat surface. The finest illustration of such an overwash plain in the State is all of that part of Long Island lying just south of the great terminal moraine, and known as the Jamaica plain toward the east (see plate 12).

When the ice front extended across a more rugged country, with valleys sloping away from the ice, the large glacial streams, heavy laden with débris, caused more or less deposition of materials on the valley bottoms often for many miles beyond the ice front. Such deposits, known as *valley trains,* are especially well developed along most of the large south-flowing tributaries of the upper Susquehanna river in the Southwestern plateau province.

Glacial boulders, or erratics, have been referred to already; they are simply blocks of rock or boulders from the top of the ice or within it which have been left strewn over the country as a result of the melting of the ice. They vary in size from small pebbles to those of many tons weight (see plate 40), and they are naturally most commonly derived from the harder and more resistant rock formations. Thus erratics from the Adirondacks are very numerous in east-central New York, some having even been transported to the southern border of the State. Erratics are often found high up on the mountains, and sometimes they have been left stranded in remarkably balanced positions.

A very extensive glacial deposit, called the *ground moraine,* is simply the heterogeneous, typically unstratified, débris from the bottom of the ice which was deposited, sometimes during the ice advance, but most often during its melting and retreat. When it is mostly very fine material with pebbles or boulders scattered through its mass, it is known as *till* or *boulder clay.* The pebbles or boulders of the till are commonly faceted and striated as a result of having been rubbed against underlying rock formations.

Another type of glacial deposit of unusual interest is the *drumlin* which is, in reality, only a special form of ground moraine material or till. The typical drumlins of New York State are low, rounded mounds of till with elliptical bases and steeper slopes on the north sides and with long axes parallel to the direction of ice movement (see plate 42). In height they rarely exceed 200 feet, being most often less than 100 feet. The origin of the drumlins has not yet been satisfactorily determined, though it is known that they formed near the margin of the ice either by the erosion of an earlier drift layer, or by accumulation beneath the ice under peculiarly favorable conditions, as perhaps along longitudinal crevasses or fissures. One of the finest and most extensive exhibitions of drumlins in the world is the region of western New York from Oswego and Syracuse to west of Rochester. Thousands of drumlins there rise above the general level of the Ontario plain, the New York Central Railroad, from Syracuse to Rochester, passing through the very midst of them.

Another type of glacial deposit in the low hill or hillock form is the *kame* which, in contrast with the drumlin, always consists of stratified drift. Kames are seldom as much as 200 feet high, and typically they have rounded bases though frequently they are very irregular in shape. At times they exist as isolated masses or hills or in small groups, while often they are associated with the unstratified deposits of the moraines. When they are grouped, deep depressions occur between the hills to form what is called the knob and kettle structure. Kames were formed at or near the margin of the retreating ice, and so they are found in all parts of the State. They most generally occur in valley bottoms, but sometimes on hillsides or even hilltops. They are especially common along the line of the great terminal moraine (for example, on Long island), and also along the line of the important terminal moraine already described as extending from central to western New York. For example, in the vicinity of Oriskany Falls kames are so numerous as to form a striking feature of the landscape in the Oriskany valley. They were formed as deposits by débris-laden streams emerging from the margin of the ice, the water sometimes having risen like great fountains because of pressure. Such deposits are now actually in process of formation along the edge of the great Malaspina glacier of Alaska.

During the retreat of the ice, glacial lakes were numerous, especially after the ice front had passed north of the Susquehanna-Allegany divide because the north-sloping valleys were dammed by the ice thus ponding the waters in the valleys. Some materials were directly deposited from the glacier in those lakes, but more was brought in by débris-laden streams flowing from the land already freed from the ice. Such glacial lakes and their deposits are common and of unusual interest, but they are described under a subsequent heading.

In conclusion we may say that the deposition of glacial materials, like glacial erosion, has not changed the major topographic features of the State. The general tendency of ice deposits has been to fill or partially fill depressions and thus to diminish the ruggedness of the topography.

Great Lakes history. The Great Lakes certainly did not exist before the Ice age, but instead the depressions in that region were occupied by stream channels. During the very long erosion period (already discussed) from the Paleozoic to the Cenozoic, no lakes, except possibly a few very small ones due to landslides, beaver dams, etc., could have existed. As compared to such an immense length of time lakes are, at most, only ephemeral features of the earth's surface because they are soon destroyed either by being filled with sediments, or by having their outlets cut down, or both. Since the Great Lakes are of postglacial origin it is, then, proper to ask how they came into existence. During preglacial time, as we have learned, broad valleys were cut out along belts of weak rock in the Great Lakes region, and these old valleys, to a considerable extent at least, account for the present depressions, but not for the closed lake basins. This idea of preglacial stream valleys is not at all opposed by the fact that some of the lake bottoms are now well below sea level because there has been a notable subsidence of the region since preglacial time. The surface of Lake Erie is 573 feet and its deepest point 369 feet above sea level, and the surface of Lake Ontario is 247 feet above and its deepest point is 491 feet below sea level. The greatest depth (738 feet) of Lake Ontario is well toward the east end and not far from the south shore, and if we consider this deep place as due to preglacial erosion, we ought to find an outlet channel. But no such outlet channel exists because the whole eastern end of the lake is certainly rock-rimmed. As Tarr has said: "There could hardly be a valley over 700 feet deep and broad enough to form the continuation of the preglacial Ontario valley, which is so completely obscured by drift that not the least trace of it has been found on the surface."[1] To assume that this deep part of the basin was produced by warping of the land is not borne out by examining the exposed strata on all sides. It seems quite certain therefore that the preglacial Ontario depression was here considerably deepened by ice erosion. The conditions were very favorable for such erosion because the rocks were chiefly soft Ordovician shales; because the ice flowed through a deep preglacial valley; and because there was unusual crowding of ice into this valley due to the pronounced deflection of a great ice current around the Adirondacks on the west side. Strong arguments might be adduced to show that by ice erosion, portions, at least, of all the lake basins were appreciably deepened. Even so, however, we have not yet accounted for the present closed basins. In the writer's opinion the two most important phenomena which contributed to the formation of the closed basins of the Great Lakes were the great drift accumulations along the south side and the tilting of the land downward on the north side of this region. The deep drift deposits certainly must have been very effective in damming up the south or southwest-flowing preglacial streams of the region. For example, the deep channel of the so-called Dundas river (see figure 27) has been drift-filled as proved by many well borings, and a distinct moraine extends around the southern half of Lake Michigan. The great dumping ground of ice-transported materials from the north was in general along the southern side of the Great Lakes and southward. Late in the Ice age the land on the northern side of the Great Lakes region was lower than it is today as proved by the tilted character of certain well-known beaches of extinct glacial lakes (see below). Such a differential tilting or warping of the land must have helped to form the closed basins by tending to stop the southward or southwestward drainage from the region. To summarize, we may say that the present Great Lakes basins are due to a combination of factors, the more important of which were: the formation of preglacial valleys by stream erosion; a more or less deepening of these valleys by ice erosion; the great accumulation of glacial débris along the southern side of the Great Lakes region; and the tilting of the land downward toward the north.

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[1] Tarr's Physical Geography of New York State, p. 235.

We are now ready to trace out the principal stages in the history of the Great Lakes during the final retreat of the ice sheet. When the ice front had receded far enough northward to uncover the southern end of Lake Michigan, and an area west of the present end of Lake Erie, small lakes were formed against the ice walls. One of these has been called Lake Chicago which drained past

Chicago through the Illinois river and into the Mississippi; and the other Lake Maumee which drained southwestward past Fort Wayne through the Wabash river and into the Ohio and Mississippi.

At a still later stage the conditions shown on the map (figure 30) existed. Lake Chicago was then much larger, and Lake Maumee had expanded into the extensive Lake Whittlesey which covered nearly all of Lake Erie as well as the immediately surrounding country. Lake Whittlesey was at a lower level than the former Maumee and the outlet past Fort Wayne ceased, but the drainage from Whittlesey was westward by a large river flowing through small Lake Saginaw and into Lake Chicago, which latter still emptied through the Illinois river.

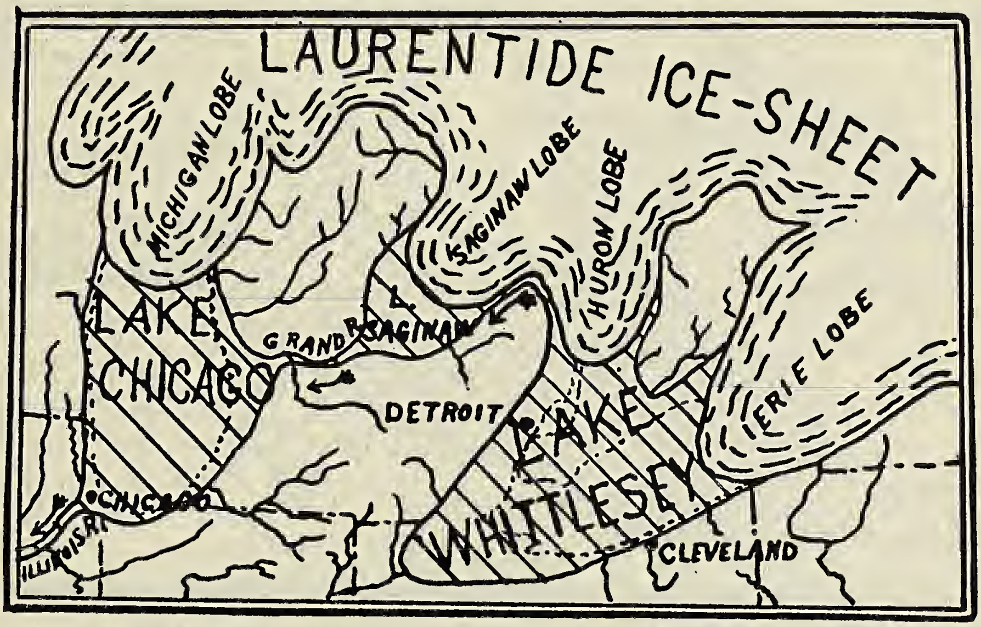

FIG. 30 A later stage of Great Lakes history, showing how the eastern and western ice margin lakes combined with outlet past Chicago.

After Taylor

At a still later stage (figure 31) Lake Saginaw merged with the waters of the Erie basin to form the large Lake Warren which extended along the ice front eastward nearly to central New York. As the map clearly shows, the Finger lakes basins of New York were then occupied by Warren waters, while Niagara Falls were not then in existence because that region was also covered by Lake Warren. Lake Warren continued to discharge westward into Lake Chicago and the Mississippi river until a very late stage, when the waters had worked their way along the border of the Ontario ice lobe into the Mohawk valley which was then occupied by a large glacial lake (held up by the Ontario ice lobe on the west and the

Champlain-Hudson lobe on the east) and thence into the Hudson valley. Thus, for the first time, the Great Lakes drainage passed eastward into the Atantic ocean. This great volume of water draining eastward was often in the form of distinct streams with the ice front for north wall and the high land of the Helderberg escarpment for wall on the south. Many of these glacial stream channels, which are still plainly visible, have been studied and mapped by Professor Fairchild.

By successive stages, due to a complete removal of ice from central New York and a draining of the glacial lake in the Mohawk valley, the waters dropped to below Warren level until Lake Iroquois was formed (see figure 32). The old beach line of this lake is still plainly visible in New York, and, with some slight interruptions it has been traced from near the mouth of Niagara river to just north of Rochester, past Syracuse, along the south, east, and north sides of Oneida lake, and thence along the western base of the Tug Hill plateau to near Watertown. The well-known ridge road between Niagara river and Rochester is built on the old Iroquois beach deposit. Lake Iroquois covered somewhat more than the present area of Lake Ontario, and the distinctly lower water level here than in the Erie basin allowed the modern Niagara river to begin its history by flowing northward over the limestone plain near Buffalo. Meantime the waters of the upper lake basins had merged to form Lake Algonquin which at first probably dis-

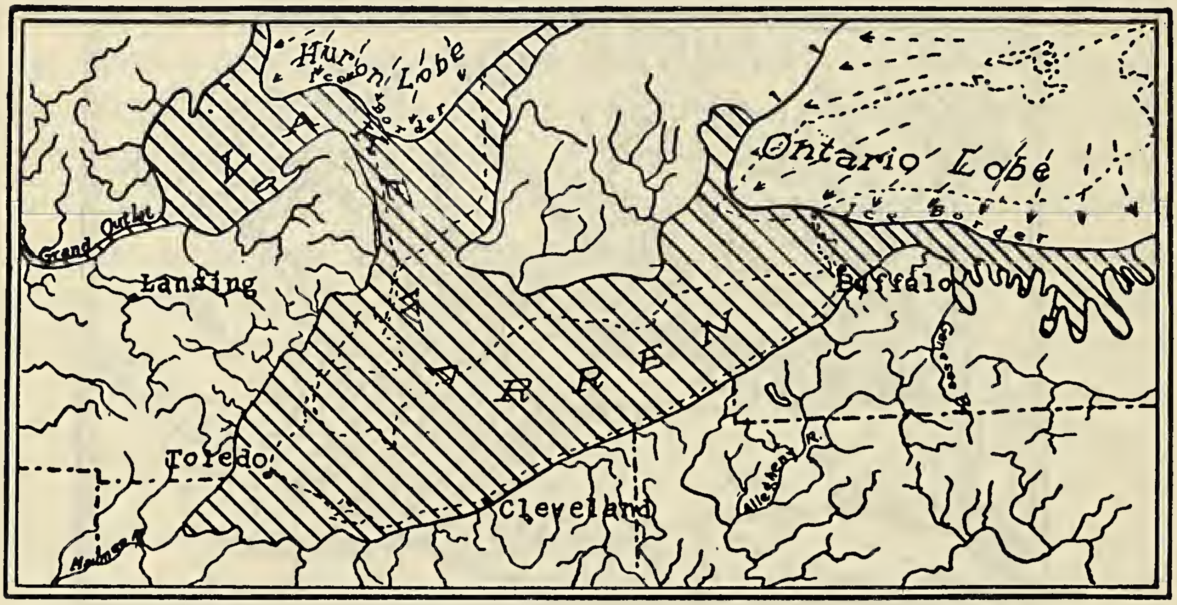

FIG. 31 Glacial Lake Warren. At this stage the discharge of the lake was still westward to Lake Chicago and the Mississippi river, while the eastern end of the lake covered most of the Finger Lakes region of New York.
Modified from Taylor & Leverett, U. S. G. S.

charged past Detroit though the Erie basin and into Lake Iroquois by way of Niagara river. Later, however, when the ice had withdrawn a little farther northward, a lower outlet was opened through the Trent river by which Lake Algonquin drained into Lake Iroquois. We know that the old Trent river channel is now higher than the Detroit outlet, but some of the proofs for the existence of the Trent outlet are as follows: the presence there of a large, distinct river channel; the convergence of the beaches toward that channel; and the fact that the land was then considerably lower on the north or northeast side of Lakes Ontario and Erie than on the south side. For example, in following the old Iroquois beach we find that it now gradually rises to higher levels until, even at Watertown, it is several hundred feet higher than near the mouth of the Niagara river. This tilting of the beach has been due to rise of the land since the lake existed, and it is evident, therefore, that, during the Algonquin-Iroquois stage, the Trent river channel was lower than that past Detroit. During this Lake Iroquois stage the waters of all the Great Lakes region discharged through the Mohawk-Hudson valleys, and the volume of water which flowed past Rome, Utica, and across the preglacial divide at

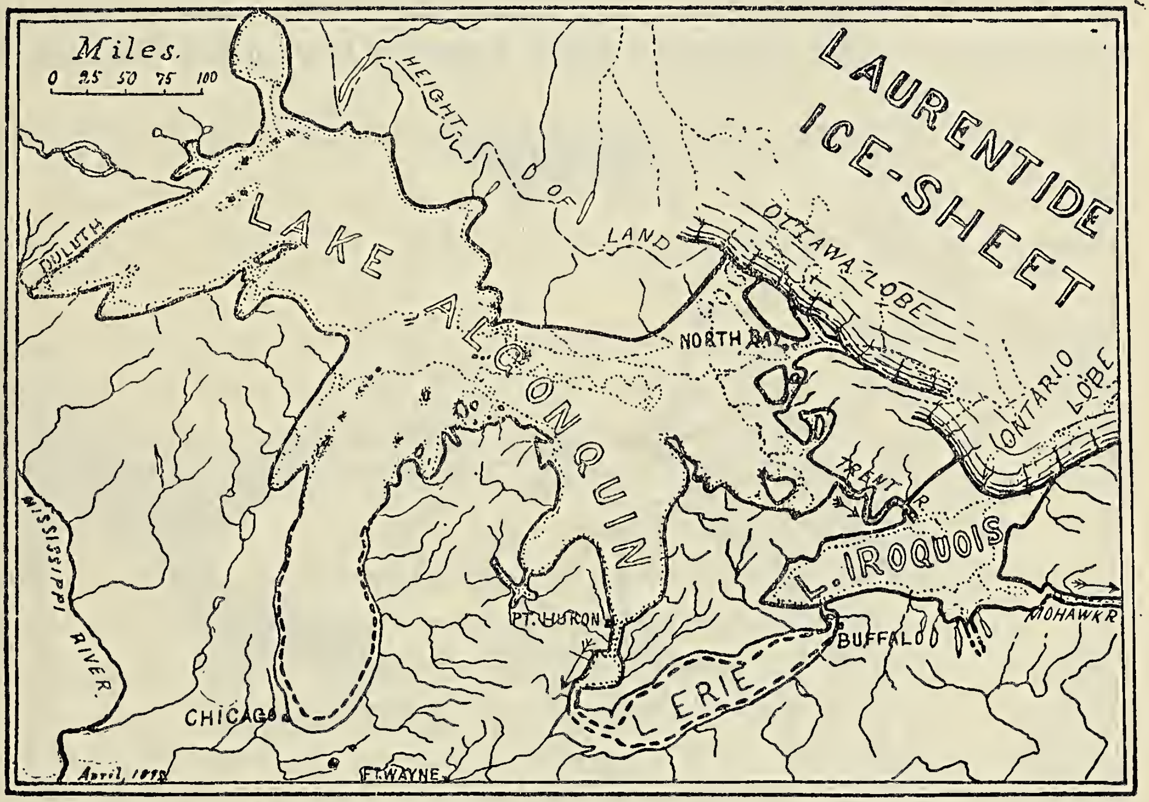

FIG. 32 The Algonquin-Iroquois stage of Great Lakes history when the ice had retreated far enough to open the outlet through the Mohawk valley. After Taylor

Little Falls must have been as great, if not greater, than that which now goes over Niagara Falls. Much of the gorge cutting at Little Falls was accomplished by this great volume of water. The St Lawrence valley was still buried under the ice.

Still later the ice withdrew enough to allow the Algonquin-Iroquois waters to discharge along the northern base of the Adirondacks and into what appears to have been ice-ponded waters in the Champlain basin, and thence southward into the Hudson valley. The Mohawk river outlet was thus abandoned.

Finally the ice retreated far enough to free the St Lawrence valley when the waters of the Great Lakes region dropped to a still lower level, bringing about the Nipissing Great Lakes stage (see figure 33). The Nipissing lakes found a low outlet through the Ottawa river (then free from ice) and into the Champlain arm of the sea. Postglacial warping of the land brought the Great Lakes region into the present condition, but this, and the Champlain subsidence, being really postglacial features will be described toward the end of the chapter.

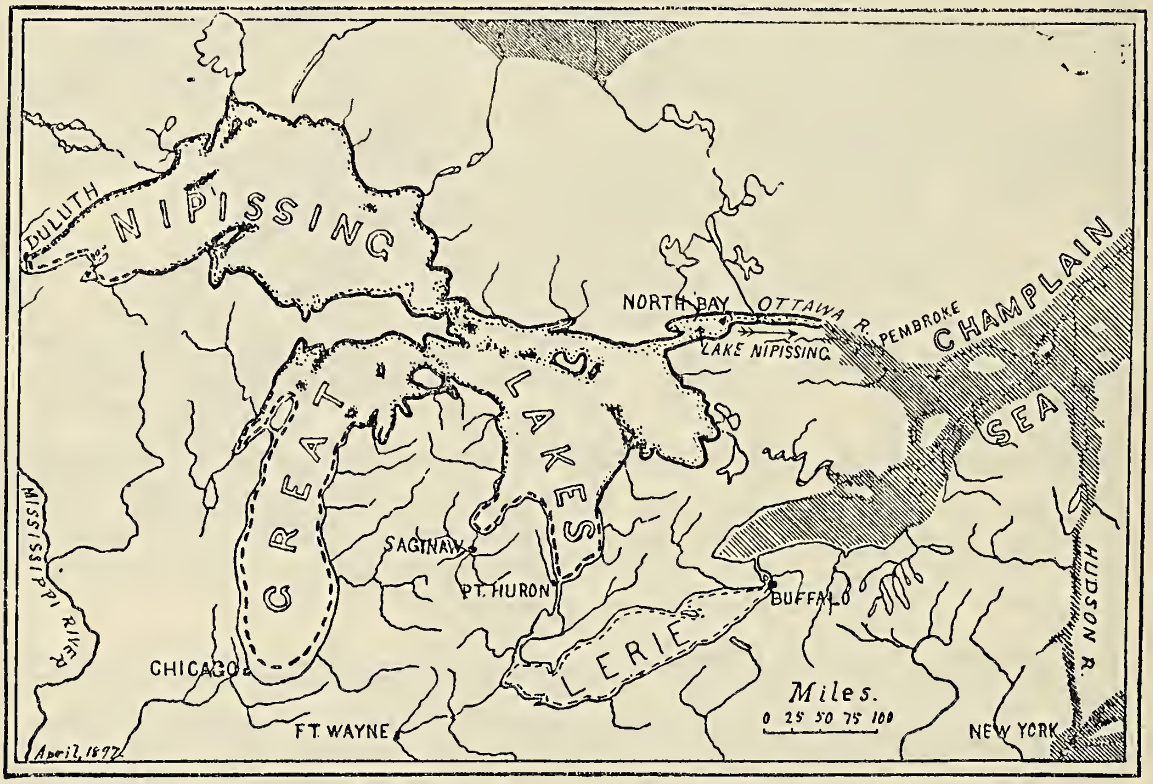

FIG. 33 The time of the Nipissing Great Lakes and Champlain submergence. The shaded area on the east was covered by sea water.

After Taylor

Other existing lakes and their origin. Counting all, from the smallest to the largest, there are within the borders of New York State thousands of lakes, and these constitute one of the most striking differences between the geography of the present and that of preglacial time. These lakes are widely scattered over the State though there are three general regions worthy of particular mention as follows: the Finger lakes region of western New York; the Adirondack mountains; and the southeastern portion of the State. The linear type of lake is by far the most common, this being preeminently true of the Finger lakes and to a large extent of those of the Adirondacks. It is well known that most of the larger lakes, especially those of the linear type, occupy portions of preglacial stream channels. All the existing lakes are due, either directly or indirectly, to glacial action, and among the ways by which such bodies of water were formed are these: by building dams of glacial drift across old river channels; by ice erosion; and by the filling of the numerous depressions which were formed by irregular deposition of the drift (kettle holes, etc.). Hundreds of small lakes, often not more than mere ponds in size, belong to the last named type, while most of the large lakes are due chiefly to the existence of drift dams.

Much has been written concerning the origin of the Finger lakes, and only the briefest summary will here be given. All are agreed that the lakes of this remarkable group occupy preglacial valleys, most of which, at least, contained north-flowing streams. These lakes have dams of glacial drift across their lower (north) ends, and the dams have largely contributed to the formation of the lakes, being in some cases perhaps the sole cause of the lakes. In the cases of the two largest lakes, Seneca and Cayuga, there is, however, strong evidence that the preglacial channels were notably deepened by ice erosion.[1] As Professor Tarr says: "They offered broad channel ways, along which the ice streams moved much more easily than upon the neighboring irregular hilltops. Not only was the movement more rapid, but the depth of ice was greater. The position of the rocks, dipping southward, and the nature of the friable shales conspired toward rapid erosion; and so these north and south preglacial valleys were markedly deepened. Evidence of this comes from the side streams. The rock bottoms of the preglacial valleys of these tributary streams are not now below the level of the lake water in the southern part of the valley (Cayuga). If all the drift could be removed and the streams be allowed to flow along the line of the course of the preglacial valleys and enter the valley of Lake Cayuga as it now stands, excepting that it be robbed of water, they would tumble between 300 and 400 feet in a distance of about a mile, commencing their descent near the present lake margin, a most unnatural condition for mature tributaries near their mouth."[1] Thus it appears quite certain that the preglacial Cayuga and Seneca valleys, at least, were notably deepened by ice erosion below the level of the mouths of the preglacial tributary streams.

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[1] The surfaces of Seneca and Cayuga lakes are respectively 444 and 381 feet above sea level, and their deepest places are respectively 186 and 119 feet below sea level.

Most of the numerous Adirondack lakes have been formed by irregular damming of preglacial valleys by glacial drift. It is quite the rule to find the outlets of these lakes flowing through such loose materials. By ice erosion many of the favorably situated valleys were no doubt somewhat modified, but up to the present time we have no good example of a lake basin produced by that agency. The hard Precambrian rocks were not so easily eroded by the ice. Attention is called to the prominent lake belt in the middle of the Adirondack province, running in a north-northeast by south-southwest direction. This belt comprises many well-known lakes as Placid, Saranac, Tupper, Long, Blue Mountain, Big Moose, and Fulton Chain lakes. Sometimes small lakes or ponds are situated well toward mountain tops because of favorably located drift deposits. A good example of such a lake lies at an altitude of 2620 feet well toward the top of Crane mountain in Warren county.

Many of the existing Adirondack lakes were formerly of larger extent as proved by delta deposits above the present lake levels. Two lakes of this class recently coming under the writer's observation are Schroon lake in Warren-Essex counties, and Piseco lake in Hamilton county. The water of Schroon lake was once fully 70 feet higher when it extended some eight or ten miles farther up the Schroon river, with a branch reaching over the area of the present Paradox lake, and also for some six or eight miles farther southward to cover all the lowland around Chestertown, and with a prominent branch extending over the area of the present Brant lake. Piseco lake was at one time clearly twenty feet higher, and then extended several miles farther northward.

The valley of Lake Champlain was favorably situated for ice erosion, and it bears evidence of having been vigorously glaciated though it has not been proved that the existing closed basin is chiefly due to ice erosion. At the close of the Ice age, tide water entered the valley. The present lake basin is due principally to a combination of late elevation of the land, with greater uplift on the north; heavy glacial accumulations toward the north; and possibly some deepening as a result of ice erosion.

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[1] Tarr's Physical Geography of New York State, pp. 181–82.

Lake George is justly famous because, from the standpoint of length and depth in proportion to width, no other lake in the State occupies such a remarkable depression. This depression (valley) has been determined by ordinary erosion along lines of prominent faults. There was a preglacial divide where the "Narrows" are now located, and this divide appears to have been considerably lowered by ice erosion when part of the Champlain ice lobe plowed its way through the deep, narrow valley. The waters are now held in by glacial deposits at each end.

In southeastern New York, from the Connecticut state line westward to the southern Catskills in Sullivan county, there are many lakes, though all are comparatively small. With few exceptions these lakes appear to be of the usual drift dam type. Greenwood lake, at an altitude of 621 feet and extending from Orange county across the state line into New Jersey, is the largest in this part of the State. Three small lakes near the summit of Shawangunk mountain, and close to its eastern edge, deserving special mention are: Mohonk, Minnewaska, and Awosting. Mohonk lake, which is so widely known both because of its remarkable situation and as a place where so many peace conferences have been held, may be taken as the type of the three. The altitude of this lake is more than 1200 feet, or about 1000 feet above the base of the mountain ridge on which it is located. It is almost completely surrounded by walls of hard Shawangunk conglomerate, while the lake basin itself is in the soft underlying Ordovician shales. This lake does not appear to owe its origin to a dam of glacial drift, but rather to ice erosion in the soft shales at a place where they had already been exposed to view before the oncoming of the ice. Such patches of shale occur at several places on the mountain.

Near the very western end of the State lies another lake remarkably situated. This is Lake Chautauqua, famous as the great center of Chautauqua assemblies. The altitude of the lake is 1338 feet, and its northern end is near the edge of the steep front of the Southwestern plateau province where it overlooks the low Erie plain. The drainage is southward into the Allegheny river, but the narrow place near the middle of the lake strongly suggests a preglacial divide there. As Tarr says: "If this view be true, Chautauqua lake is made up of parts of two valleys, one north-sloping, the other south-sloping, and each dammed by heavy morainic accumulations."[1]

Extinct glacial lakes. Hundreds of extinct glacial lakes are known to be scattered over the State. Some of these existed only during the time of the ice retreat, but others persisted for a greater or less length of time after the Ice age. Lakes Warren, Iroquois etc., already described, were fine examples of the first type. North-sloping valleys were particularly favorable for the development of glacial lakes during the retreat of the ice because the ice front always acted as a dam across such valleys, thus allowing the waters to become ponded. When the ice front stood across the northern ends of the Finger Lakes valleys, the waters in those valleys were ponded at much higher levels than they now are, and the ancient water levels are more or less clearly marked by the old beach lines.

Perhaps the finest example of a large, wholly extinct glacial lake is Black lake, which occupied a good portion of the Black river valley on the western side of the Adirondacks. This lake, small at first, was formed by ponding the waters in the upper Black river valley around Forestport, Oneida county, in front of the waning (northward retreating) ice lobe in the Black river valley. Its first discharge was probably southward past Remsen. Further retreat of the ice lobe permitted an enlargement of the lake to the region around Boonville, and the discharge was then southward along the channel of the present Lansing kill. The deep, narrow gorge a few miles south of Boonville, along this stream, was mostly cut by the fairly large stream which drained the glacial lake at this stage. The southward discharge through this channel appears to have been into the Lansing Kill lake where a delta deposit was formed a few miles north of Rome and now the site of the Delta reservoir. Lansing Kill lake in turn drained through the Mohawk Valley. Still further retreat of the ice lobe allowed Black lake to expand greatly until it reached from the region around Forestport to north of Lowville, when it had a width of from five to ten miles. When the ice withdrew enough to permit a discharge of water around the north base of Tug hill, and into Lake Iroquois, the level of the lake rapidly fell until the ice barrier was completely removed. The former presence of this great glacial lake is conclusively shown by the extensive development of unquestioned delta deposits. Where the streams from the Adirondacks, especially the larger ones such as Black, Moose, and Independent rivers, emptied into the lake, delta deposits were rapidly built up to near the lake surface because those streams were heavily charged with débris from the newly drift-strewn mountains. These delta deposits became more or less merged, and they show a remarkable concordance of altitudes over the sand flat or sand plain country on the east side of Black river. This great delta deposit is several miles wide; very flat-topped except where trenched by postglacial streams; presents a steep front toward the river; and shows a depth of from 200 to 250 feet along the western edge. Figure 34 clearly shows the relation of the delta deposit to the old rocks of the valley.

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[1] Tarr's Physical Geography of New York State, p. 205.

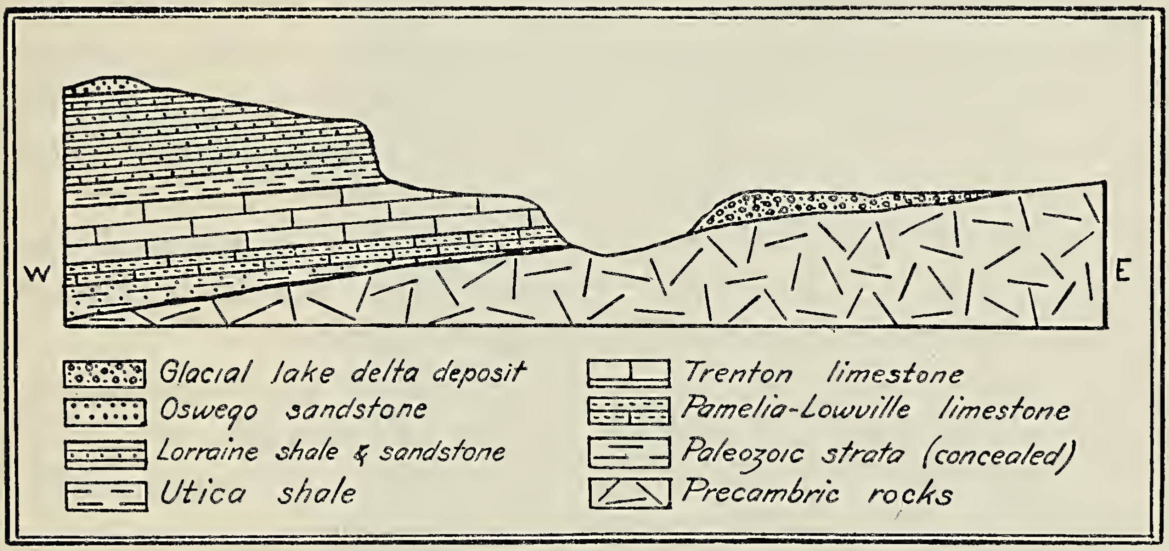

W
E
Glacial lake delta deposit
Oswego sandstone
Lorraine shale & sandstone
Utica shale
Trenton limestone
Pamelia-Lowville limestone
Paleozoic strata (concealed)
Precambric rocks

Fig. 34 East-west section across the Black river valley, 2½ miles north of Lyons Falls, showing the terraced character of the Paleozoic strata and their relations to the Precambrian Adirondack rocks. On the east side, the position of the glacial lake delta deposit is shown. Length of section 12½ miles. Vertical scale greatly exaggerated.

After W. J. Miller, N. Y. State Mus. Bul. 135

In many cases where the edge of an ice lobe extended across the mouth of an east, or west, or even south-sloping valley, glacial lakes were formed. A fine example of a glacial lake (now extinct) formed in a south-sloping valley has been called glacial Lake Sacandaga which covered many square miles of the bottom of the broad, deep valley in which Gloversville and Northville are located. Through this valley, which has a width of several miles and a maximum depth of over a thousand feet, the preglacial Sacandaga flowed southward into the Mohawk. During the general ice retreat, but when the Mohawk glacial lobe was still present, morainic deposits along the margin of the ice lobe formed an effective barrier across the mouth of the valley thus ponding the waters over the valley bottom and causing the Sacandaga to find an outlet northeastward over the low divide at Conklingville. The altitude of the lake corresponded approximately to the present 780 foot contour line, though it is quite certain that the land was then somewhat lower. This lake persisted for a good while after the disappearance of the ice because of the effective drift dam, and even today, in the spring of the year, a number of square miles of swamp in the lowest part of the valley are flooded. The lake was drained by cutting down the divide at Conklingville. It is interesting to note in passing that the construction of the proposed Sacandaga reservoir, by means of a dam at Conklingville, would almost exactly restore this former glacial lake.

Many other glacial lakes are known to have been formed by ponding of water alongside the waning Mohawk ice lobe. During the melting of the ice tongue from the Hudson and Champlain valleys, many small glacial lakes are also known to have been formed in the tributary valleys because of ice dams across them.

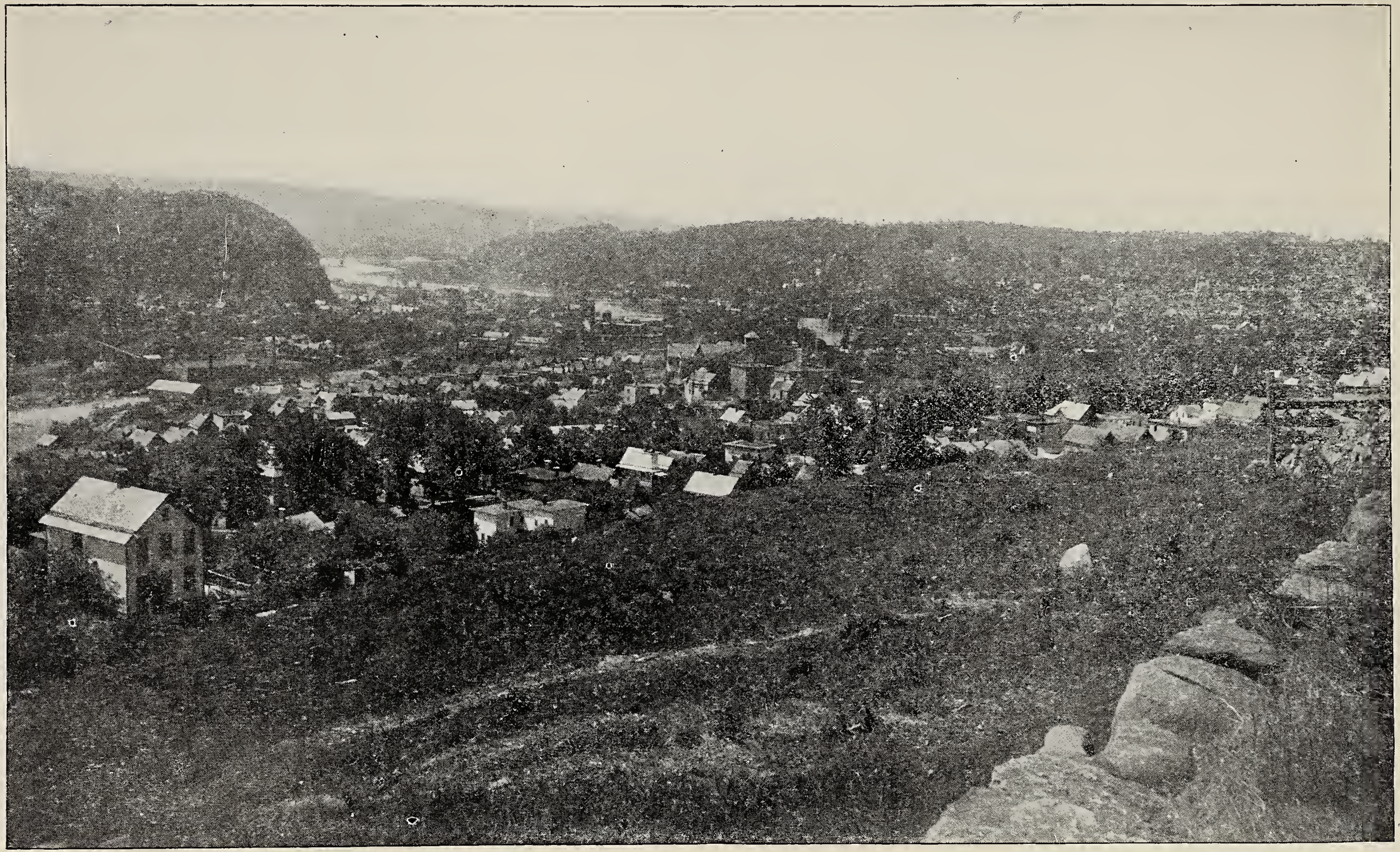
A wonderful succession of extensive glacial lakes occupied the valleys in the general vicinities of Saranac lake, Lake Placid, Keene valley, and Wilmington in the Adirondack mountains.

New York State fairly abounds in such extinct glacial lakes, and though comparatively few have yet been described, they are usually easily recognizable by means of the typical, flat-topped, delta deposits of crudely stratified sands, gravels and clays.

Drainage changes, gorges, and waterfalls. Along with its lakes, New York State is also famous for its numerous gorges and waterfalls, which are also largely due to the great Ice age. As a result of the very long preglacial erosion period, it is perfectly clear that typical, steep-sided, narrow gorges and true waterfalls must have been very uncommon, if present at all. Like lakes, such features are ephemeral because, under our conditions of climate, gorges soon (geologically) widen at the top and waterfalls disappear by retreat or by wearing away the hard rock over which they fall.

Drainage changes, aside from those already described in connection with the history of lakes, are also numerous in New York. It must be remembered that, with few exceptions (for examples, the basins of Lakes Ontario and Erie, Niagara river, and possibly the St Lawrence river), the major drainage lines of the State were little changed during the Ice age because the principal valleys were mostly the same before and after glaciation. It is the present

Plate 44



General view of the gorge at Little Falls, looking up the Mohawk river from the eastern part of the city. In the bottom of the gorge is Precambrian igneous rock (syenite), while the steep hills on either side of the river are of Little Falls (Cambrian) dolomite.

From N. Y. State Mus. Bul. 77, pl. 12

purpose briefly to describe only some of the most important and best known cases of stream changes due to the Ice age.[1]

From the standpoint of both geography and human history, the gorge at Little Falls is the most important in New York State (see figure 7 and plate 42 and also the description in chapter 2). Before the Ice age there was a divide, instead of the gorge, several hundred feet above the present river level, and it consisted of hard Little Falls dolomite. The prominence of this rock barrier was greatly increased by the tilting of the strata due to the development of the Little Falls fault. The Mohawk river flowed eastward, and the now extinct Rome river flowed westward, from this divide (see figure 35). During the Ice age the divide was lowered somewhat by ice erosion, and during the Algonquin-Iroquois stage of the Great Lakes history, (as we have learned) these lakes discharged through the Mohawk valley and across the Little Falls divide. It was the passage of this great volume of water over the divide which caused the cutting of most of the gorge as we now find it, except for the narrow trench in the hard, underlying Precambrian

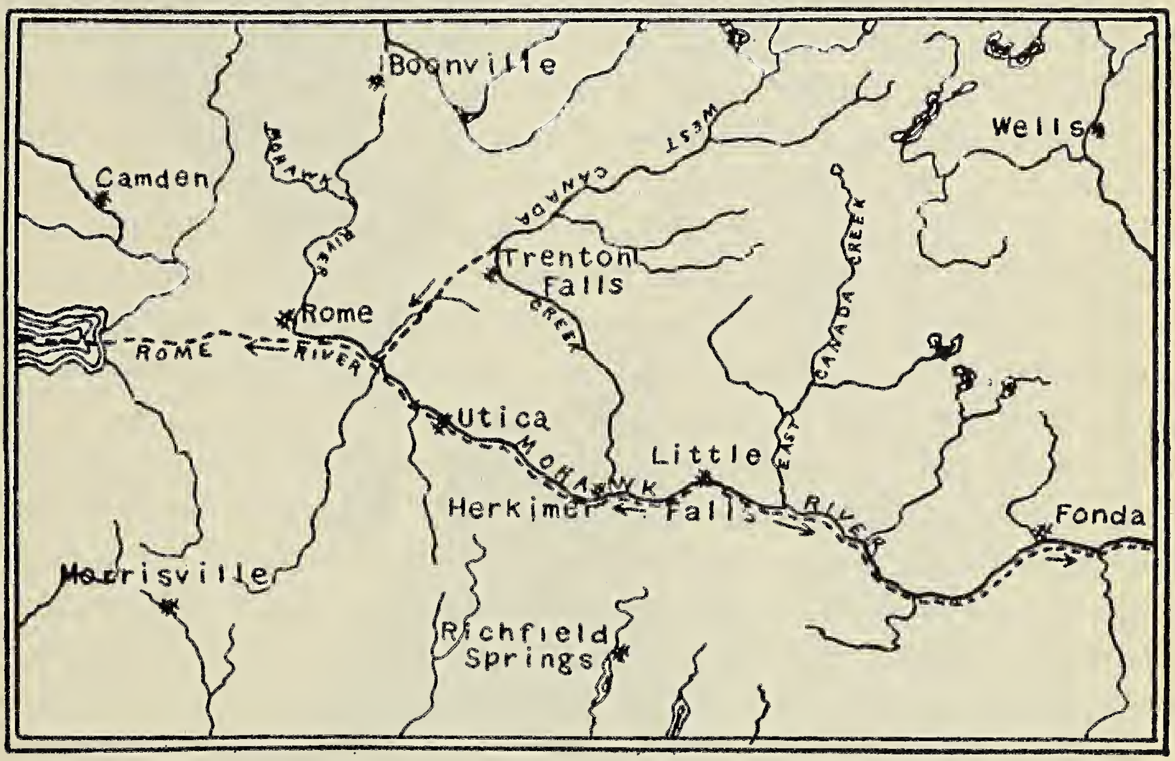


FIG. 35 Sketch map of central New York, showing the relation of preglacial to postglacial drainage. Preglacial streams shown by dotted lines only where essentially different from existing streams.

Based upon work of A. P. Brigham

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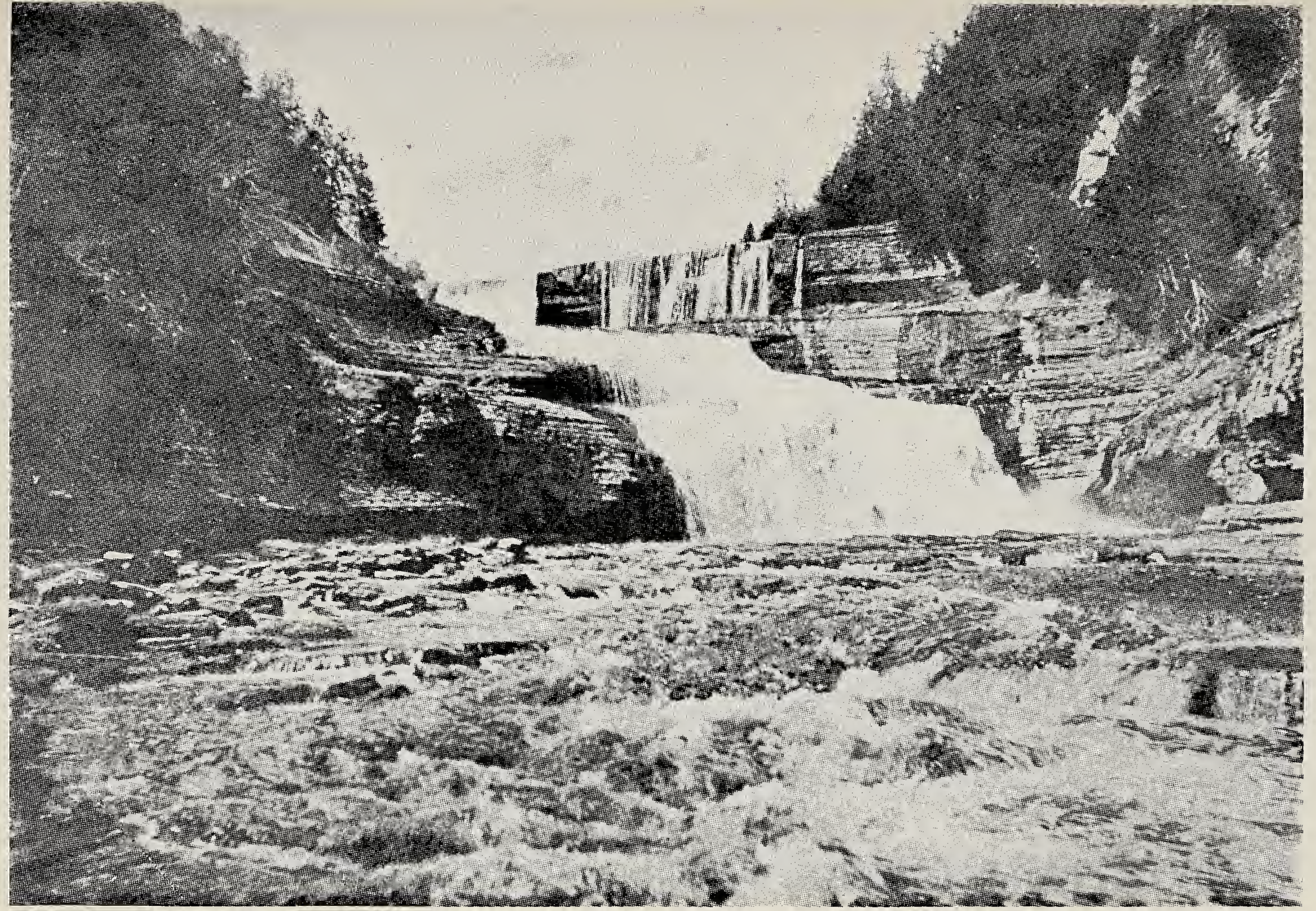
[1] All the drainage changes now to be described will be much better understood by consulting the large government topographic maps of the regions considered.

rock which is no doubt due to postglacial erosion. During the Iroquois stage an arm of the lake extended along the valley from Rome to Little Falls. All the streams from north and south which entered this arm of the lake were heavily charged with débris from the newly drift-covered regions and, the current not being strong enough to carry away the débris, the valley from Rome to Little Falls was built up (aggraded) to such an extent that, after the disappearance of Lake Iroquois, the drainage from Rome was able to continue eastward. Thus we have here a very fine example of exact reversal of drainage directly due to glaciation. By this means the upper waters of the Mohawk were added to the preglacial Mohawk.

Closely associated with the above is the postglacial history of West Canada creek and the famous chasm at Trenton Falls. The preglacial West Canada creek flowed from Prospect (upper end of Trenton chasm) past Holland Patent, through the valley of the present Nine Mile creek, and into the Rome river opposite the village of Oriskany. This channel was completely blocked by glacial drift at Prospect so that the creek was forced to find a new course southward over the limestone at Trenton Falls, and thence southeastward to its present mouth at Herkimer. The gorge, between Prospect and Trenton Falls villages, is 2½ miles long and from 100 to 200 feet deep, and it has been cut into the Trenton limestone by the postglacial stream. It contains five or six waterfalls ranging in height from 10 to 126 feet, the total drop of the water in the 2½ miles of the gorge being 360 feet (see plates 43 and 44).

In the southeastern Adirondacks, the upper waters of the Hudson river present some very interesting examples of drainage changes. In fact, it is not too much to say that the larger drainage features of that region have been more or less revolutionized as a result of glaciation. The accompanying sketch map (fig. 36) gives a fair idea of the changes, but reference to the State geologic map and to the topographic maps of the region is greatly to be desired. The State geologic map shows two distinct embayments of Paleozoic rocks forming valleys which extend northward, one to Northville and the other to Corinth, and into the mass of Precambrian rocks of the Adirondacks. It is certain that these valleys contained important preglacial streams which flowed southward out of the mountains. Now, however, the Sacandaga river enters the north end of the first named valley only to make a very sharp turn back on its course to flow across the mountains and into the Hudson at

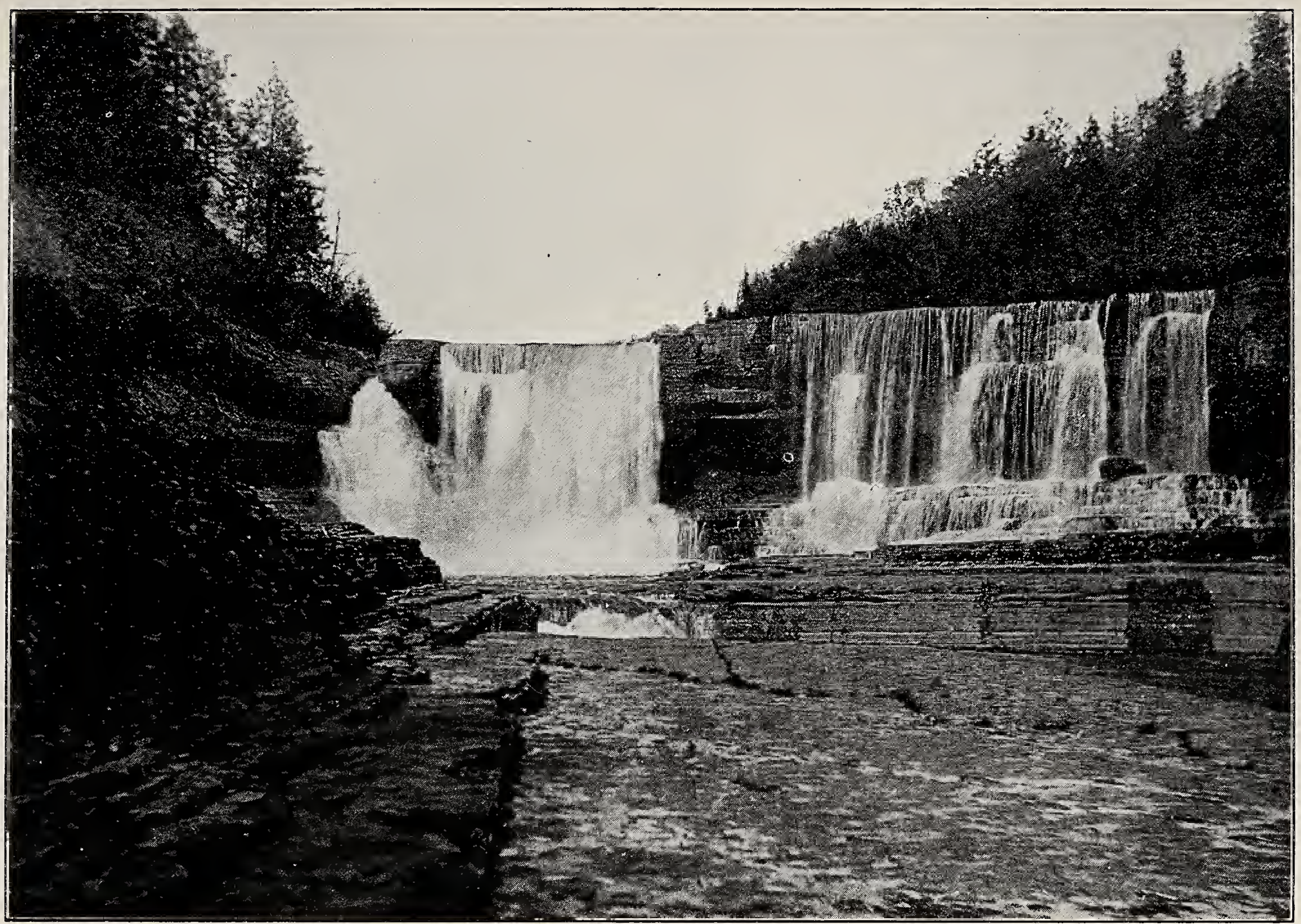
Plate 45



High Falls in the gorge at Trenton Falls, Oneida county. Both the upper and lower portions of the falls are shown, the total descent of the water being 126 feet. The rock is Trenton limestone, at its classic locality, and it abounds in early Paleozoic fossil shels. The gorge here is 200 feet deep and wholly of postglacial origin.

Photo by F. B. Guth, Utica, N. Y.

Plate 46



A nearer view of the upper portion of the High Falls, at Trenton Falls, Oneida county. The height of this fall is 50 feet.

Photo by F. B. Guth, Utica, N. Y.

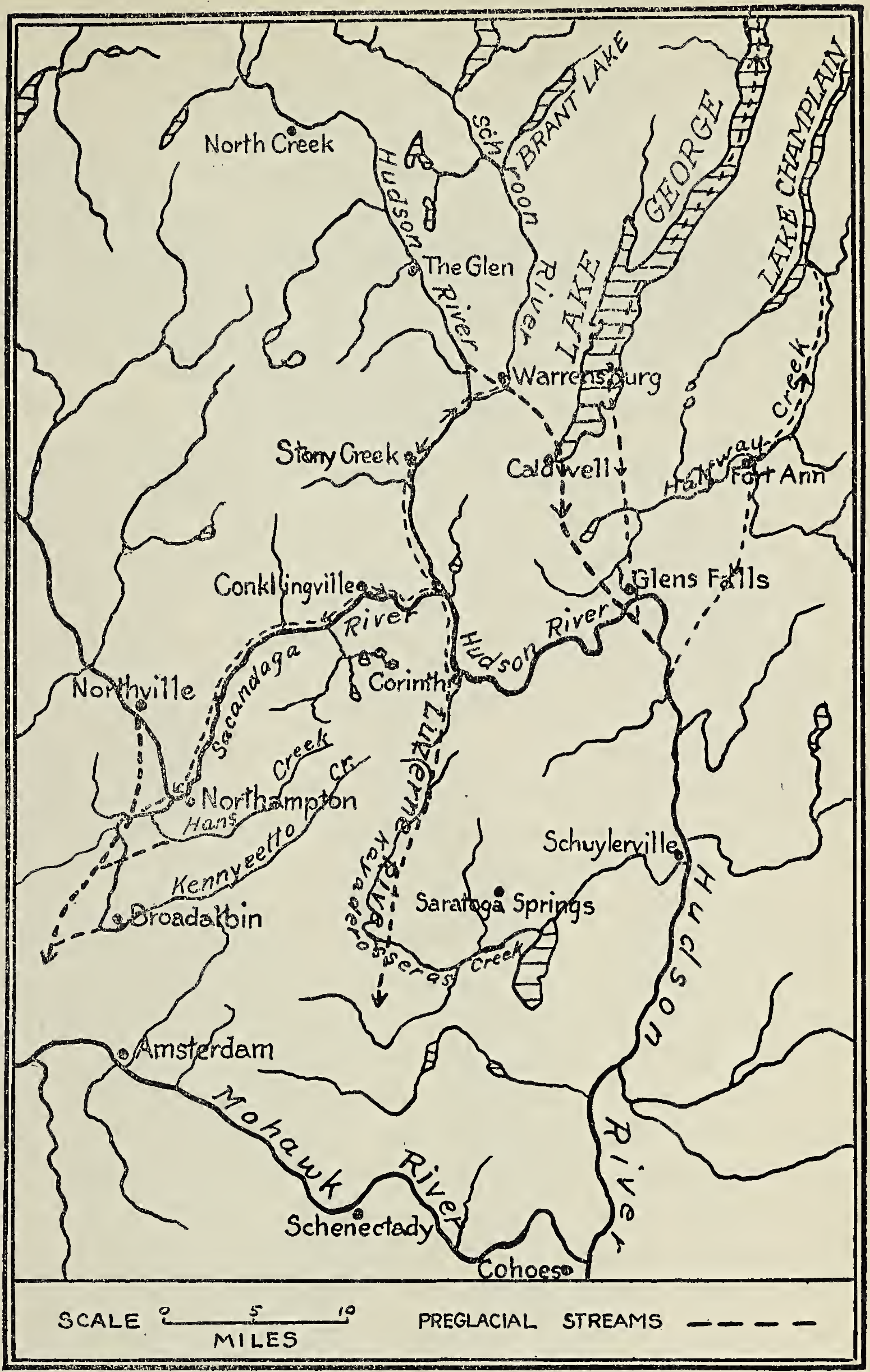


FIG. 36 Sketch map of the southeastern Adirondack region, showing the relation of the preglacial drainage to that of the present. Preglacial courses shown only where essentially different from present streams.

After W. J. Miller, Bul. Geol. Soc. Am., vol. 22

Luzerne. A preglacial divide was located at Conklingville as shown by the gorge there; the perfectly graded condition of the valley bottom westward from that place; and the flaring of the valley westward. This remarkable deflection of the river was caused by the building of a morainic blockade across the southern end of the Palezoic rock valley from Broadalbin to Gloversville. The peculiar courses of Hans and Kennyetto creeks are thus also easily explained.

The Hudson river now flows through a gorge more than 1000 feet deep just above Stony Creek station, and thence to the north end of the Paleozoic rock valley at Corinth where it turns abruptly to the northeast to flow across the Luzerne mountain ridge. The preglacial Hudson certainly did not flow through the Stony creek gorge, but rather, where the gorge now is, there was an important divide. Among other proofs for this former divide are: the deep, narrow gorge of recent origin; the flaring of the valley both northward and southward from the gorge; and the anomalous turns of both the Hudson and Schroon rivers toward the southwest through a highland region of hard rock, instead of southeastward across the much lower land between Warrensburg and Lake George. The probable preglacial channel was past Warrensburg, Caldwell and Glens Falls as shown on the map.[1] The now extinct Luzerne river started on the Stony creek divide, and flowed southward past Corinth and thence through the Paleozoic rock valley to the west of Saratoga Springs. The cause of the passage of the Hudson over the Stony creek divide was partly due to a lowering of the divide by ice erosion, but mostly to the fact that during the ice retreat the ice lobe in the Lake George depression forced the Hudson river to take a more westerly course which was continued after the melting of the ice. The deflection of the river across the Luzerne mountain divide was certainly caused by heavy drift accumulations in the Paleozoic rock valley south of Corinth.

The famous Ausable chasm in Clinton county is a fine illustration of a deep, narrow gorge cut through the Potsdam sandstone by the Ausable river since the Ice age. The river was deflected from its preglacial channel by heavy drift filling.

According to evidence recently presented by Fairchild, the lower portion of the Black river did not flow, as now, westward past

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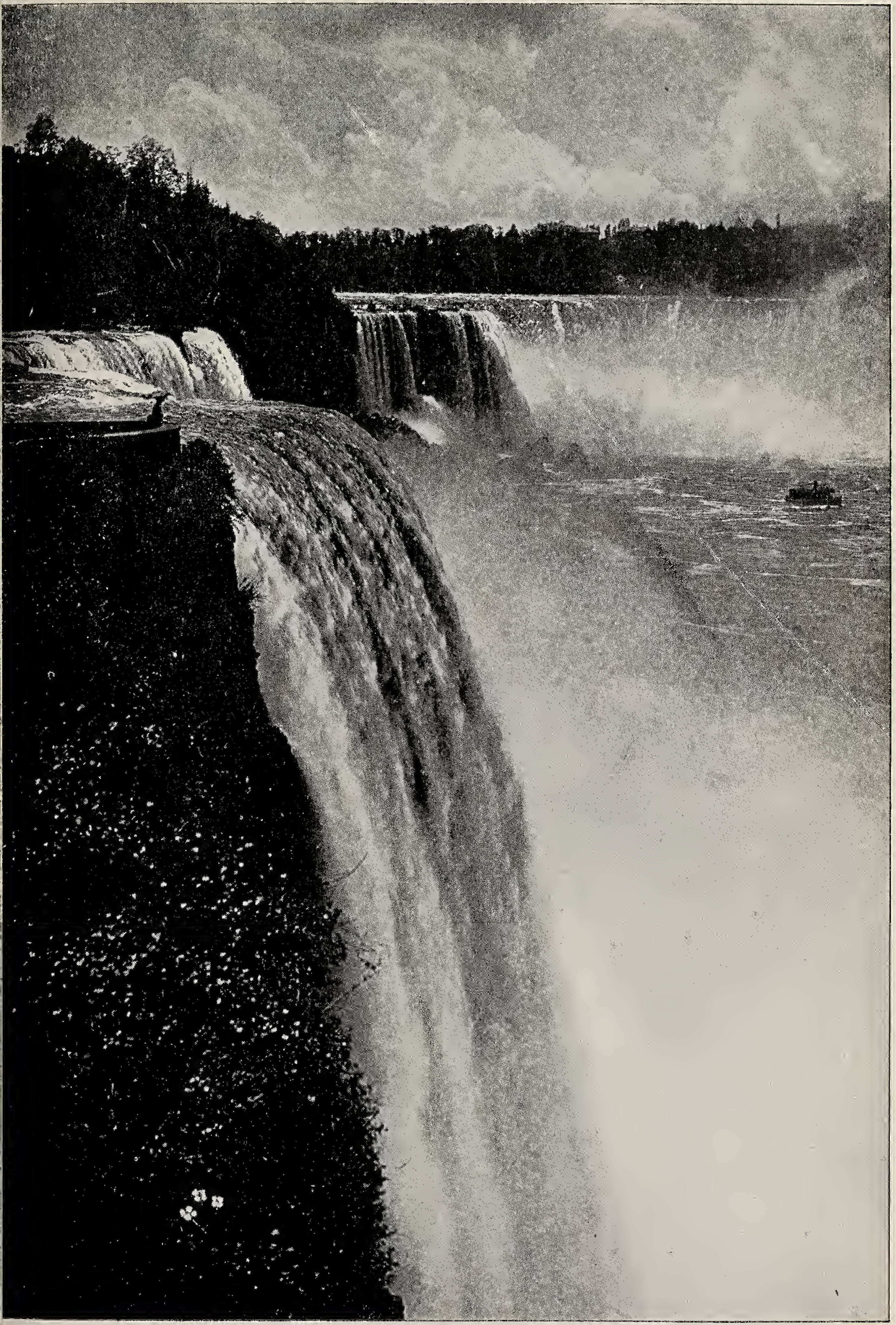
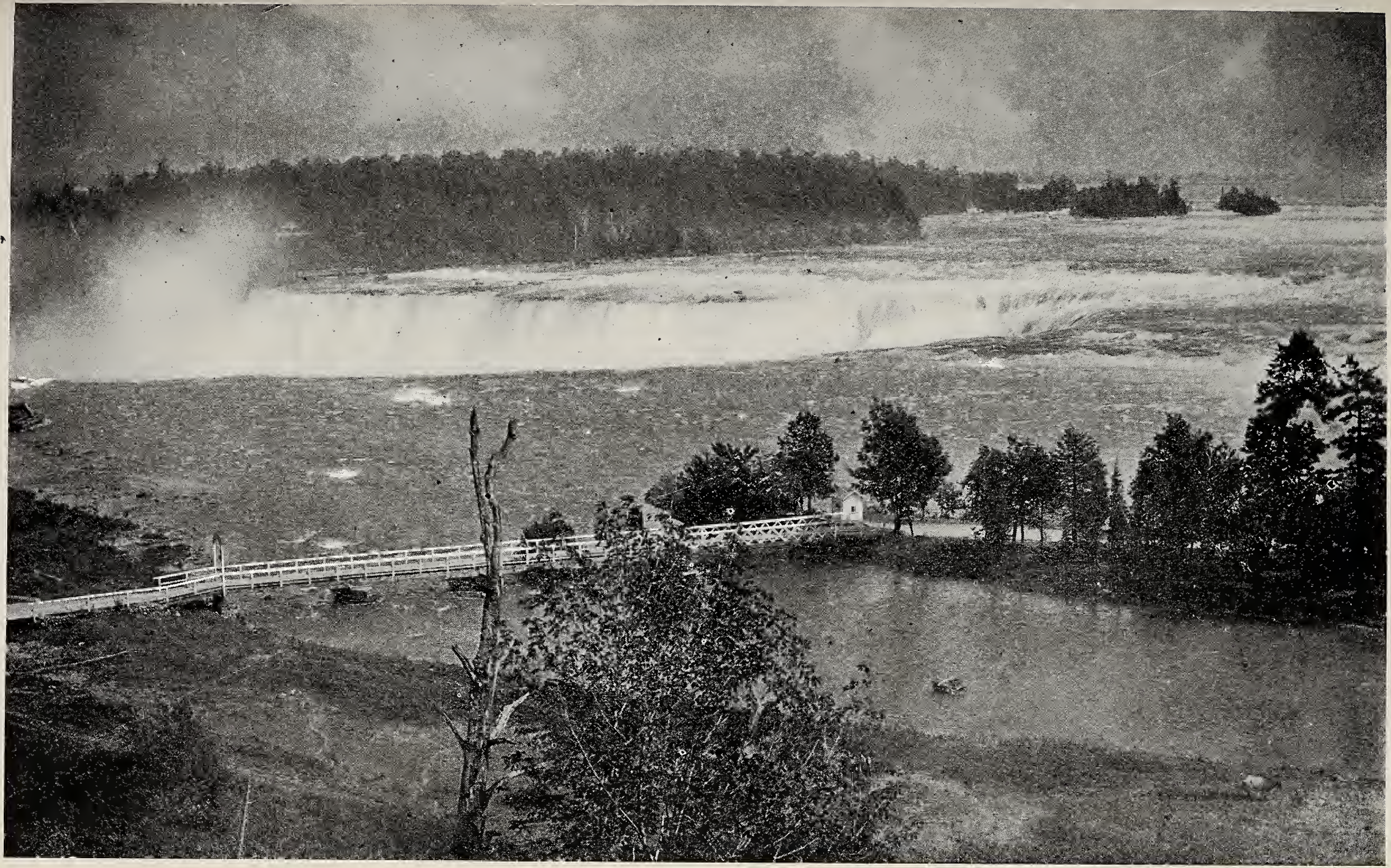
[1] A more recent study of the region has led the writer to conclude that the broader valley next to the north, that is between Warrensburg and Hillview, was probably the preglacial channel of the Hudson.



General view of Niagara Falls from the American side

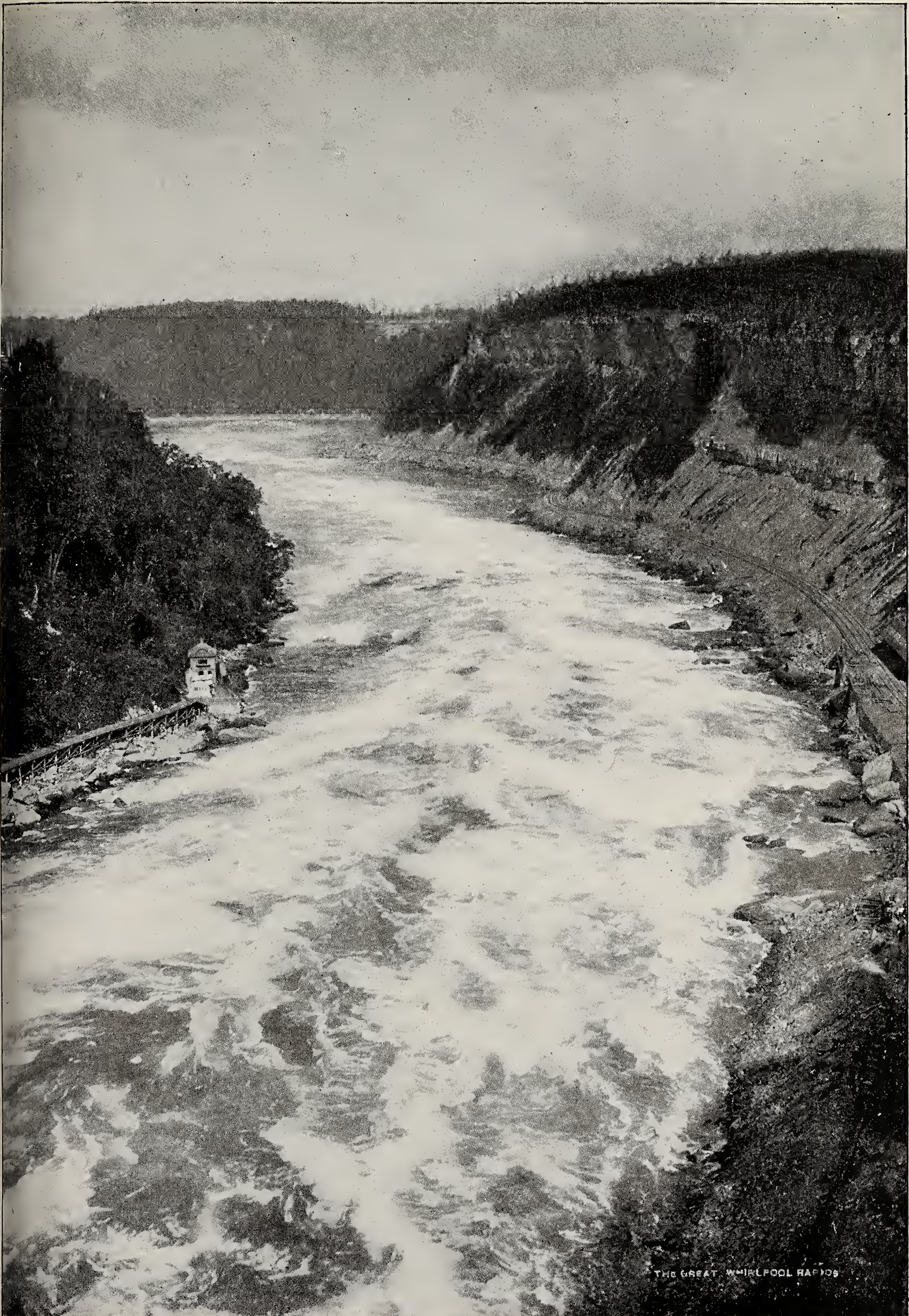
From N. Y. State Mus. Bul. 45, pl. 1

Plate 48



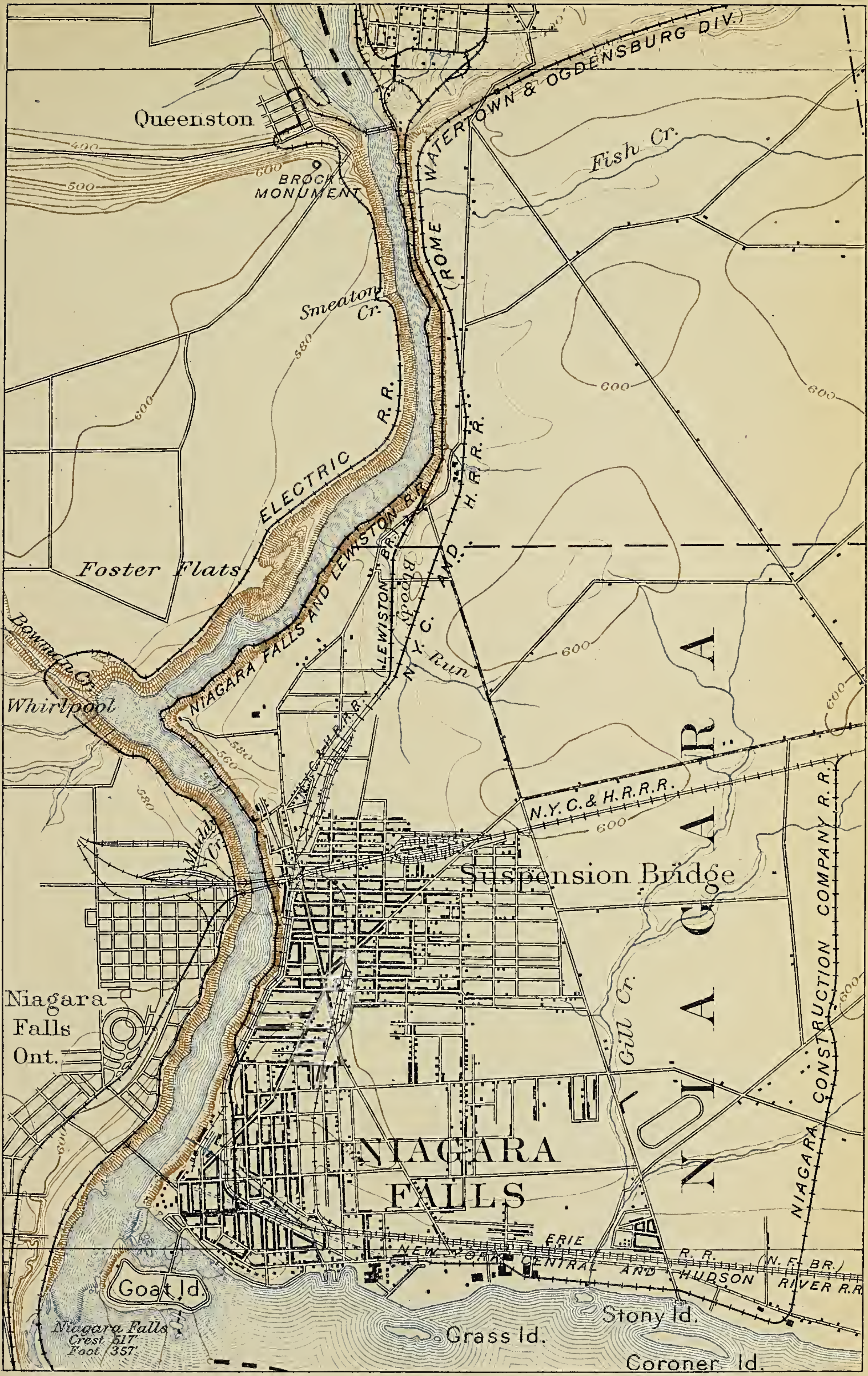
The Horseshoe falls with Goat island and the Three Sisters, as seen from the Canadian side. This view illustrates the narrowness of the gorge now forming.

From N. Y. State Mus. Bul. 45, pl. 11



The Whirlpool rapids and American bank of Niagara gorge, looking north. The rocks are nearly horizontal strata of Silurian age consisting of Lockport or Niagara limestone (forming uppermost cliff) followed downward by Rochester shale, Clinton limestone and shale (exposed near middle of bank), and Medina sandstone and shale. The gorge is here 250 feet deep.

From N. Y. State Mus. Bul. 45, pl. 10



Portion of the Niagara Falls (U. S. G. S.) quadrangle, showing the position of the Falls, the long, narrow gorge cut through the very level Ontario plain, the position of the Whirlpool and the "Niagara escarpment" at Queenston. Scale, about 1 mile to the inch.

Watertown and into the Ontario basin, but continued northward to northeastward into the St Lawrence valley and in perfect harmony with the rock structures and other drainage lines. The diversion from the preglacial course was due to heavy glacial accumulations between the villages of Black River and Evans Mills.

The deep, narrow gorges which have been cut through the steep eastern and northeastern fronts of the Tug Hill plateau are commonly called "gulfs." Of these the Whetstone gulf (see plate 8) is the most interesting, and, though little known, it is one of the finest examples of its kind in the State. Its length is two miles, and for one mile it shows a depth of 300 feet. The walls are very steep-sided to nearly vertical, especially in the upper end (narrows) where there is just room enough for the swift stream at the bottom. This gulf is certainly postglacial in origin, and it has been cut into the soft Lorraine and Utica shales. During glacial times the shales were eroded back by the ice (see above) causing the development of the steep eastern front of Tug Hill. After the ice disappeared, all east-bound streams from Tug Hill, not in their preglacial channels, rushed over the steep shale front and began to erode notches into its summit. These notches were rapidly deepened in the soft shales to form the gulfs whose heads have since been cut back to their present positions.

The world famous Niagara Falls and gorge are wholly postglacial in origin. After plunging 167 feet at the falls, the river rushes for 7 miles through the gorge whose depth is between 200 and 300 feet (plates 47, 48, 49 and 50). When the glacial waters in the eastern Great Lakes region had dropped to the Iroquois level, the Niagara limestone terrace in the vicinity of Buffalo, with its steep escarpment or northern front at Lewiston and Queenston, ceased to be covered by lake water, and Niagara river came into existence by flowing northward over this limestone plain. The river first plunged over the escarpment at Lewiston and Queenston, thus inaugurating Niagara Falls there. Since that time the falls have receded the 7 miles upstream to their present position. In figure 37 we see that soft shales underlie the hard layer of Niagara limestone, and the recession of the falls has clearly been caused by the breaking off of blocks of limestone due to undermining of the soft shales. A glance at the map (plate 50) will show that the gorge development is really taking place on the Horseshoe falls side where the volume of water is much greater, and that in a short time, geologically considered, the American falls will be dry.

The rocks exposed in the gorge walls are Niagara limestone, under which in regular order come Niagara (Rochester) shale, Clinton shale, and Medina shale and sandstone. These formations show only a slight southward dip or tilt.

The Genesee river from its source to Portageville, Wyoming county, appears to be in a mature preglacial valley. Near Portageville, however, the river plunges into a deep, narrow, rock gorge of postglacial origin, which continues for 25 miles to Mount Morris. This gorge has been cut through soft Devonian shales and shaly sandstones, and its walls are mostly nearly vertical, often rising to heights of several hundred feet. The three noted Portage falls (see plate 51) are situated just below Portageville, the upper falls plunging 66 feet, the middle falls 110 feet, and the lower falls 96 feet. According to Grabau, the preglacial course between Portageville and Mount Morris was farther westward along the present Oatka creek. A second postglacial gorge is entered at Rochester, and this continues for 7 miles to the mouth of the river. Here, also, are three falls, the first over Niagara limestone being 98 feet, the second over Clinton shale and limestone being 20 feet, and the third over Medina sandstone being 105 feet. The preglacial chan-

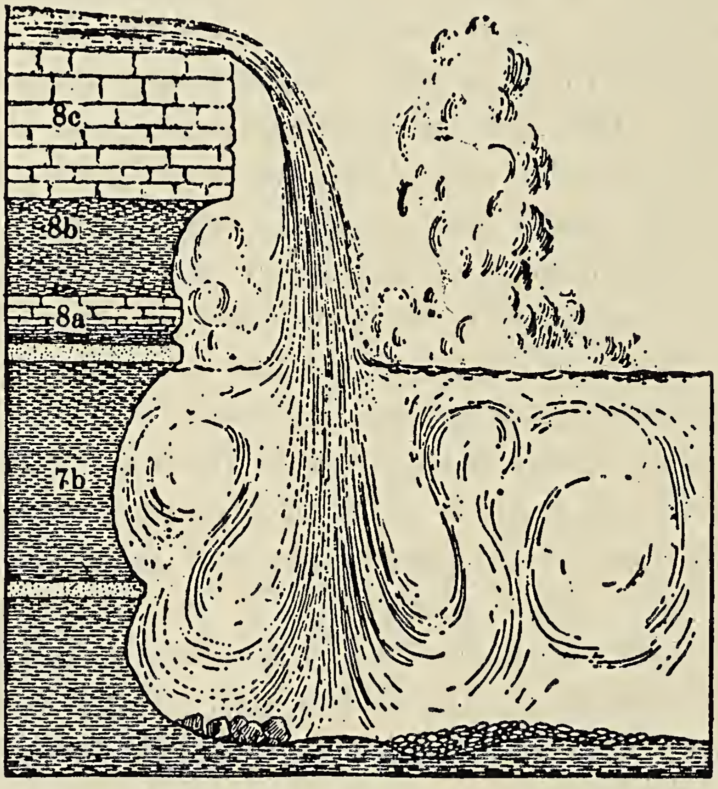
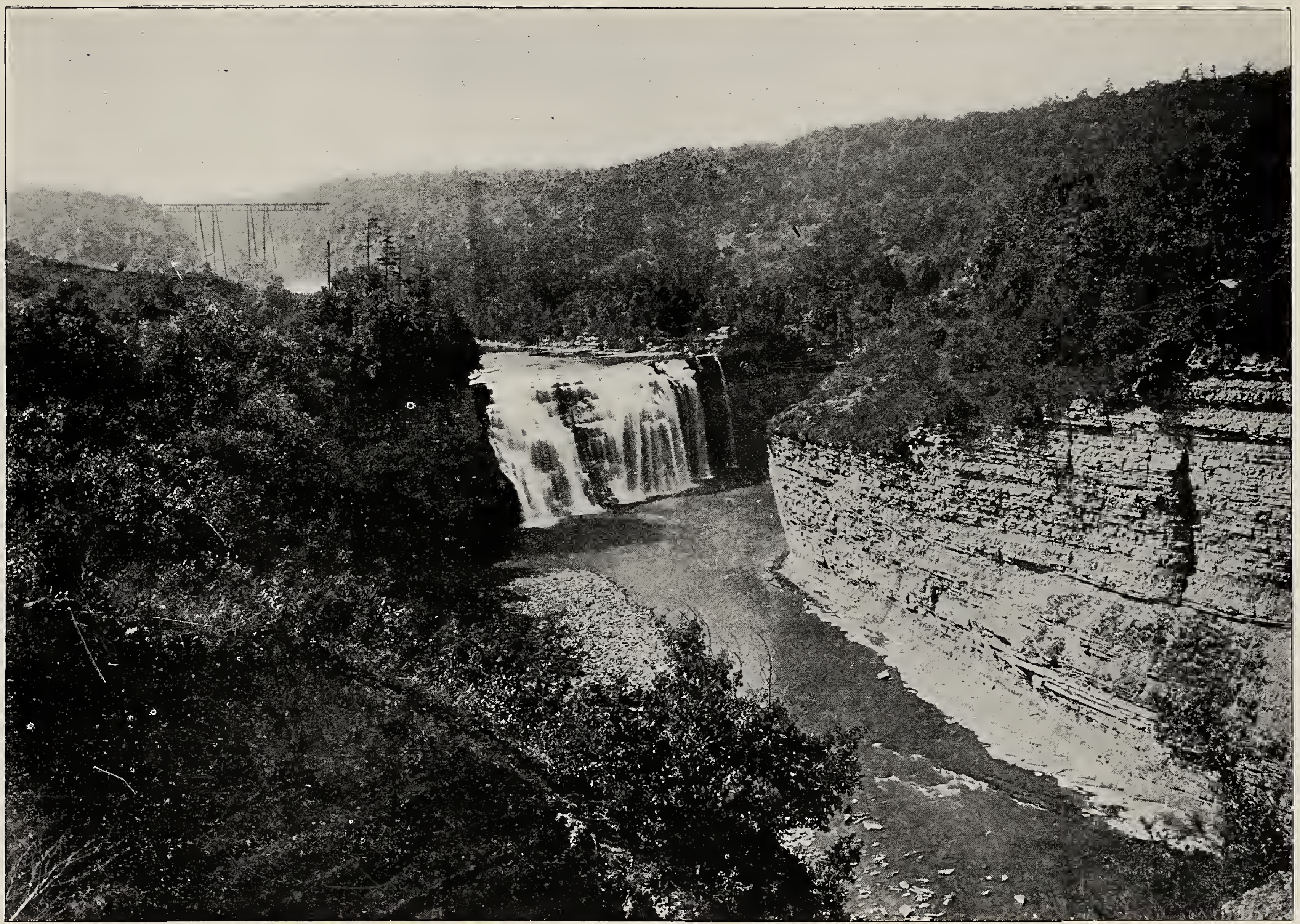


Fig. 37 Section at Niagara Falls, showing the character and position of the rock formations and the depth of water below the falls.
After Gilbert

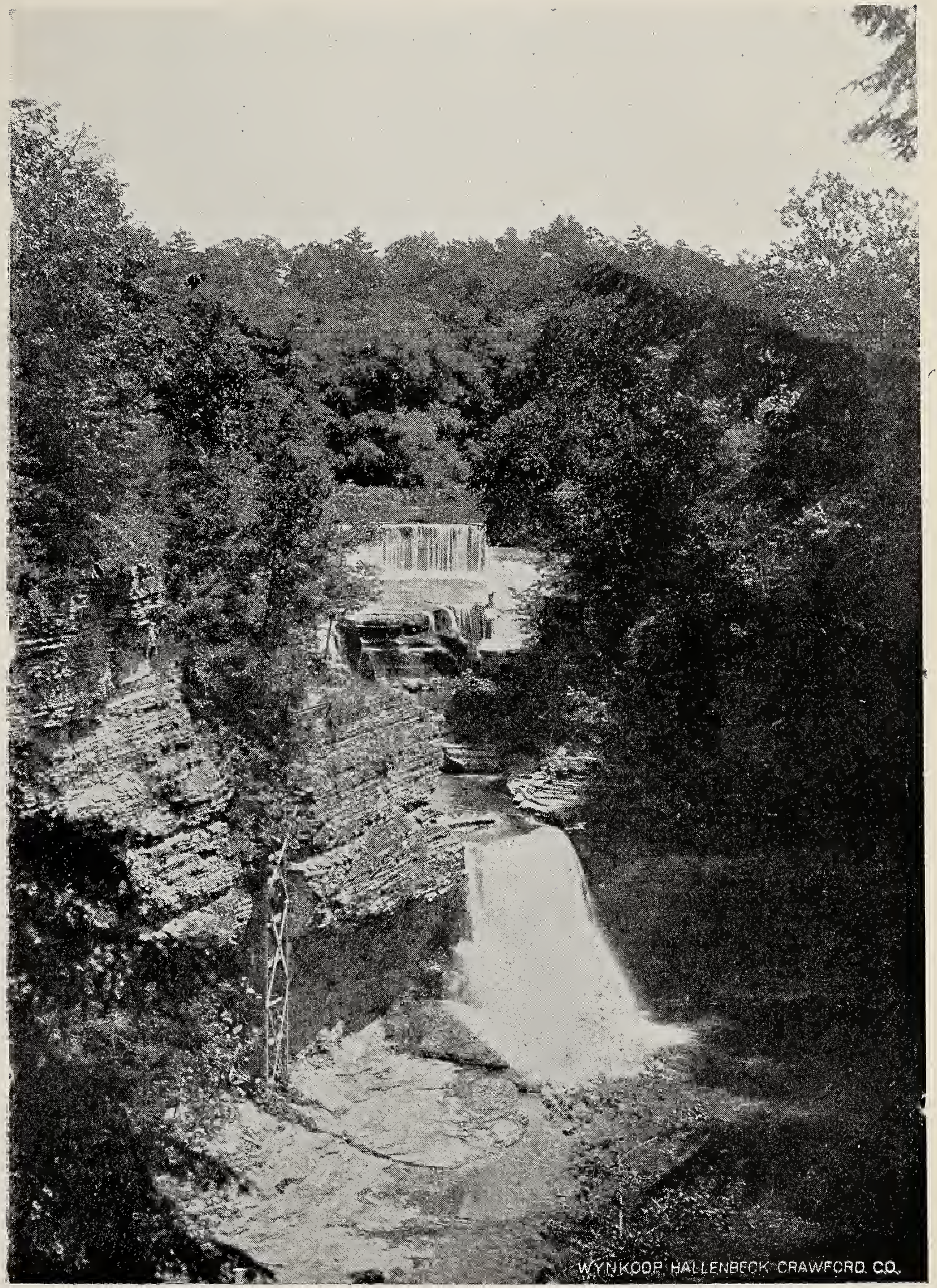
Plate 51



Middle falls and the gorge of the Genesee river just below Portageville. The falls are 110 feet high and the exposed rocks are shales and sandstones of Portage (Devonian) age. The gorge is postglacial in origin.

From N. Y. State Mus. Bul. 118, pl. 15

Plate 52



Triphammer falls and gorge at the edge of Cornell University campus, Ithaca, N. Y. The rocks are dark, thin bedded shales of Lower Portage (Devonian) age. The gorge is postglacial in origin.

From N. Y. State Mus. Bul. 19, pl. 81

nel here was probably a little to the east and through Irondequoit bay.

In the southern Finger lakes region of south-central New York there are numerous postglacial gorges, a few of the best known ones being: Watkins and Havana glens near the southern end of Seneca lake, Taughannock gorge on the west side of Cayuga lake and in northern Tompkins county, and the gorges of Butternut (Enfield), Fall, Six Mile, and Buttermilk creeks in the vicinity of Ithaca. These gorges all contain waterfalls, and they have been cut into Devonian shales or sandy shales by streams which have been either partly or wholly diverted from their preglacial courses due to heavy drift filling. In some cases, as at Watkins and Taughannock, the main north-south Seneca and Cayuga valleys were scoured and somewhat deepened by ice erosion, while in all cases the tributary channels were heavily drift filled, thus accounting for the frequent postglacial diversion of these streams which were forced to cut new channels into the steep slopes facing the main valleys.

Watkins glen is several miles long, often very narrow, and with a maximum depth of over 300 feet. Taughannock gorge, which is one and a quarter miles long and with greatest depth of about 350 feet, has in it Taughannock falls whose height is 215 feet and which takes rank as the highest true waterfall in New York State (see frontispiece). Fall creek gorge, on the north side of Cornell campus, is about a mile long, with a greatest depth of about 200 feet, and it contains Triphammer and Ithaca falls. The Butternut creek (Enfield) gorge is two miles long, with maximum depth of over 300 feet.

In Chautauqua county there are numerous gorges or so-called gulfs which have been cut through the steep front or escarpment of the western border of the Southwestern plateau province. A fine example is the gulf south of Westfield, which is several miles long and from 300 to 400 feet deep. These are also postglacial channels which have been worn into the soft Devonian shales. The steepness of the shale escarpment here, as in the case of Tug hill, was more than likely produced by ice erosion, while the preglacial north-flowing streams had their channels partially or completely filled with glacial débris so that the streams now often flow in postglacial channels. The conditions are here very similar to those of the Finger lakes region already described.

Length of time since the Ice age. Estimates of the duration of the glacial epoch by the most able students of the subject vary from 500,000 to 1,500,000 years, these estimates being based on such criteria as amount of erosion and weathering of the earliest till sheets (in Mississippi valley), times necessary for the various advances and retreats of the ice sheets, etc. Although a closer calculation is well nigh impossible because of the variability of the factors involved from time to time, it is nevertheless certain that, from the geological standpoint, the Ice age was of short duration, while, from the standpoint of known human history, it was immensely long.

Estimates of the length of time since the close of the Ice age are perhaps more satisfactory, though it must be remembered that the close of the Ice age was not at the same time for all places. The ice retreated northward very slowly and when, for example, southern New York was free from the ice, northern New York was still glaciated. The best estimates for the length of time since the close of the Ice age in New York State are based upon the rate of recession of Niagara falls. We have learned that the Niagara river began its work about the time the glacial waters in the Erie-Ontario regions had dropped to the Iroquois level, and that the falls were first formed by the plunging of the river over the Niagara limestone escarpment at Queenston and Lewiston.

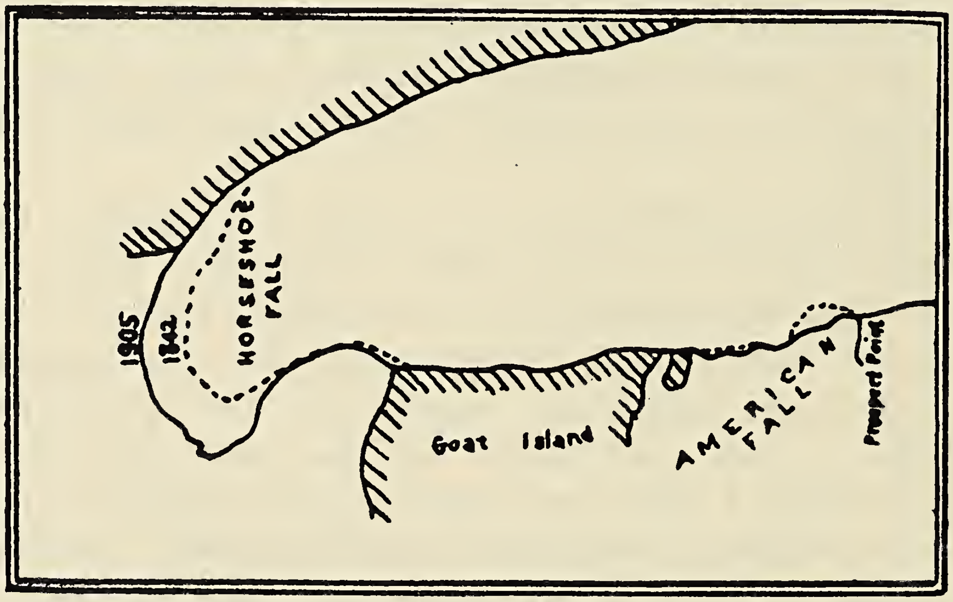


FIG. 38 Sketch map showing the relation of the crest of Niagara Falls in 1842 to that of 1905. Based upon actual surveys. The retreat of the inner portion of the Horseshoe Fall was more than 300 feet.

Modified after Gilbert, U. S. G. S. Bul. 306, p. 20

Studies based upon actual surveys, drawings, daguerrotypes, photographs, etc. made between the years 1842 and 1905, have shown that the Horseshoe falls had receded about 5 feet a year, while the American fall between 1827 and 1905, had receded about 3 inches a year. Thus the gorge cutting is clearly taking place on the Canadian side. The length of the gorge is 7 miles, and if we consider the rate of recession to have been always 5 feet a year, the length of time necessary to cut Niagara gorge would be something over 7000 years. But the problem is not so simple, since we know that at the time of, or shortly after, the beginning of the river, the upper lakes drained out through the Trent river, and then still later through the Ottawa river. So it is evident that, for a good part of the time since the ice retreated from the Niagara region, the volume of water passing over the falls was notably diminished, and hence the length of time for the gorge cutting increased. The best estimates for the length of time since the ice retreated from the Niagara region vary from 7000 to 50,000 years, an average being about 25,000 years. In a similar way the time based upon the recession of St Anthony's falls, Minnesota, range from about 10,000 to 16,000 years. While closer estimates are practically impossible, it is at least certain that the time since the Ice age is far less than its duration, and that, for the region of New York State, the final ice retreat occurred only a very short time ago.

When we consider the slight amount of weathering and erosion of the latest glacial drift, we are also forced to conclude that the time since the close of the Ice age in New York is to be measured only by some thousands of years. Thus kames, drumlins, extinct lake deltas, and moraines with their kettle holes have generally been very little affected by erosion since their formation.

Champlain subsidence and recent elevation of New York State. We have already shown that, about the beginning of the glacial epoch, the region of New York State, especially along the eastern side, was much higher than it is today, positive proof for this being afforded by the submerged Hudson river channel which must have been cut when the land was higher. Toward the close of the Ice age, and shortly after (Champlain epoch), we know that the land had subsided to a level even lower than that of today. It was during this period of subsidence that the lower Hudson and St Lawrence channels were submerged, and that the sea coast was transferred to more nearly its present position. But as the land was even lower than now, the lowlands of Long Island and the vicinity of New York City were under water, and a narrow arm of the sea extended through the Hudson and Champlain valleys to join a broad arm of the sea which reached up the St Lawrence valley and even into the Ontario basin (see figure 33). This Champlain sea existed at the time of the Nipissing Great Lakes already described. Champlain sea beaches, containing marine shells and the bones of walruses and whales, have been found at altitudes of about 400 feet near the southern end of Lake Champlain, to 500 feet at its northern end, and 600 or more feet at the eastern end of Lake Ontario. In the lower Hudson river valley the deposits of this age are about 70 feet above sea level, and at Albany a little over 300 feet. The altitudes of these so-called raised beaches show how much lower the land was during the time of greatest submergence, and that the subsidence was most toward the north.

The most recent movement of the earth's crust over the area of the State was the very recent gradual elevation which expelled the Champlain sea and left the land at its present altitude. The altitudes of the raised Champlain beaches show that the greatest elevation was on the north. The warping of the Iroquois beaches already described occurred at this same time. Actual surveys during the past century have proved that the upward movement in the northern Great Lakes region is still progressing at the rate of 5 inches in 100 miles in 100 years.

APPENDIX

CONSTRUCTION AND USES OF GOVERNMENT CONTOUR MAPS

A number of plates, comprising portions of government topographic (contour) maps, have been introduced into this book for the purpose of illustrating the typical relief features of various parts of the State. Since many persons are not familiar with these maps and their uses, a brief explanation is here given.

These topographic maps, which are called sheets or quadrangles, are rectangular in shape and bounded by latitude and longitude lines. The size of each map is about 17½ inches high by 11½ to 16 inches wide, the latter varying with the latitude. In New York State the scale is nearly always 1 to 62,500 or nearly one mile to the inch, such a sheet or quadrangle covering an area of just one-sixteenth of a square degree. The most valuable feature of these maps is the fact that the surface configuration (relief) of the country is so accurately shown, this feature being explained by the accompanying figures and the following description which is generally found printed on the back of each map: "Relief is shown by contour lines in brown. Each contour passes through points which have the same altitude. One who follows a contour on the ground will go neither up hill nor down hill, but on a level. By the use of the contours not only are the shapes of the plains, hills, and mountains shown, but also the elevations. The line of the sea coast itself is a contour line, the datum or zero of elevation being the mean sea level. The contour line at, say, 20 feet above sea level is the line that would be the sea coast if the sea were to rise or the land to sink 20 feet. Such a line runs back into the valleys and forward around the points of hills and spurs. On a gentle slope this contour line is far from the present coast line, while on a steep slope it is near it. Thus a succession of these contour lines far apart on the map indicates a gentle slope; if close together, a steep slope; and if the contours run together in one line, as if each were vertically under the one above it, they indicate a cliff...... The contour interval, or vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval varies according to the character of the area mapped; in a flat country it may be as small as 5 feet; in a mountainous region it may be 200 feet. Certain contours, usually every fifth one, are accompanied by figures stating elevation above sea level. The heights of many definite points, such as road corners, railroad stations, railroad crossings, summits, water surfaces, triangulation stations, and bench marks, are also given. The figures in each case are placed close to the point to which they apply, and express the elevation to the nearest foot only. . . . All water features are shown in blue, the smaller streams and canals in full blue lines, and the larger streams, lakes, and the sea by blue water lining. . . . The works of man are shown in black, in which coloring all lettering also is printed. . . . Houses are shown by small black squares which in the densely built portions of cities and towns merge into blocks. Roads are shown by fine double lines, trails by single dotted lines, and railroads by full black lines with cross lines. Other cultural features are represented by conventions which are easily understood. The sheets composing the topographic atlas are designated by the name of a principal town or of some prominent natural feature within the quadrangle and the names of the adjoining published sheets are printed on the margins. They are sold

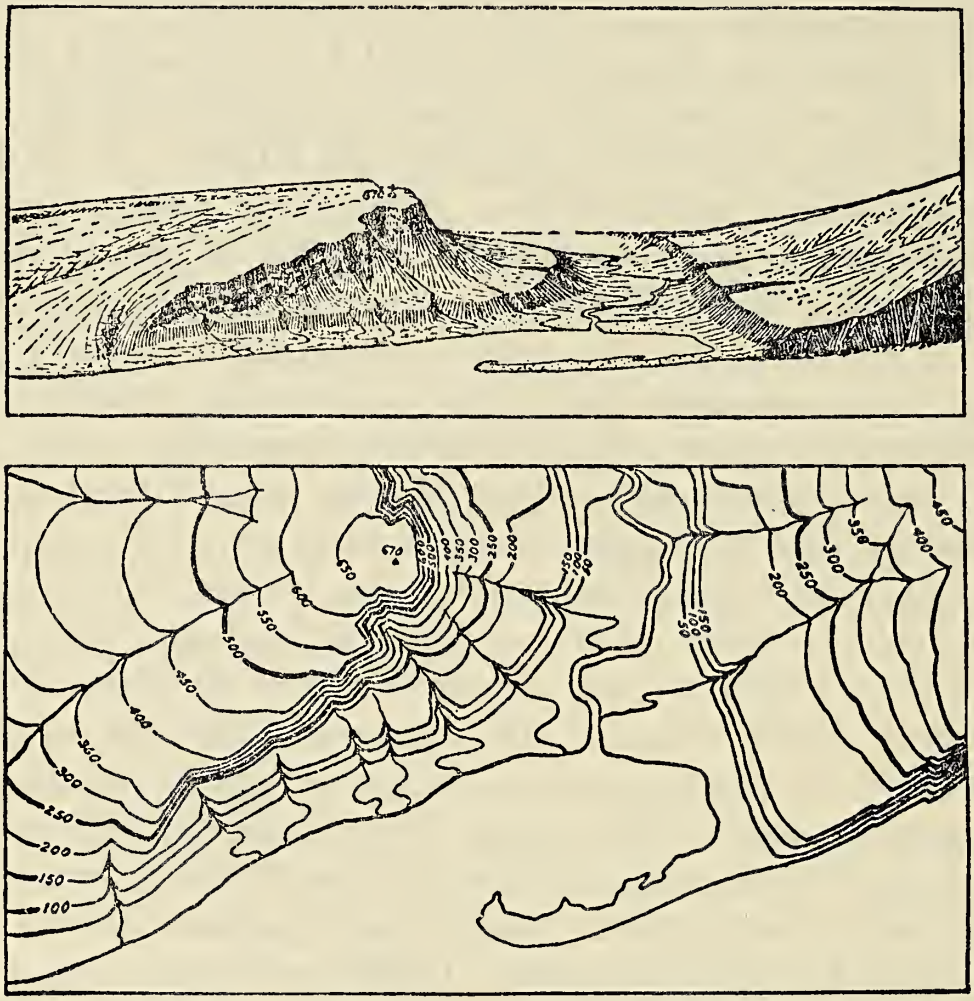


Fig. 39 Ideal sketch and corresponding contour map (U. S. G. S.).

at ten cents each when fewer than 50 copies are purchased, but when ordered in lots of 50 or more copies, whether of the same or of different sheets, the price is six cents each."

These maps are published by the United States Geological Survey, and orders for them should be sent to the director of that bureau at Washington, D. C. The order should be accompanied by cash or a post office money order. Each quadrangle has a special name by which it must be ordered. A large portion of New York State has been covered by such topographic surveys and, in order to know how to get the map covering a given region, reference should be made to the Index to Atlas Sheets for New York State. This index may be procured free of charge by dropping a post card to the Director of the United States Geological Survey.

The value of these maps to teachers of geography and physical geography would be difficult to overestimate, and every school should have a supply of these maps readily accessible. For the teaching of home geography as well as that of other parts of the State, for examples, Niagara Falls, the Thousand Islands, New York City and vicinity, etc., no other map is comparable because, in addition to the ordinary features, the relief (topography) of the land is shown in detail. In other states, also, many places of importance or geographic interest have been covered by such maps.

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The University of the State of New York

New York State Museum

JOHN M. CLARKE, Director

PUBLICATIONS

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These reports are made up of the reports of the Director, Geologist, Paleontologist, Botanist and Entomologist, and museum bulletins and memoirs, issued as advance sections of the reports.

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1920–21. (Bul. 239–240) 209p. il. maps. *Out of print.*
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These reports cover the reports of the State Geologist and of the State Paleontologist. Bound also with the museum reports of which they form a part.

Geologist's annual reports 1881–date. Rep'ts 1, 3–13, 17–date, 8vo; 2, 14–16, 4to.

In 1898 the paleontologic work of the State was made distinct from the geologic and was reported separately from 1899–1903. The two departments were reunited in 1904, and are now reported in the Director's report.

The annual reports of the original Natural History Survey, 1837–41, are out of print.

Reports 1–4, 1881–84, were published only in separate form. Of the 5th report 4 pages were reprinted in the 39th museum report, and a supplement to the 6th report was included in the 40th museum report. The 7th and subsequent reports are included in the 41st and following museum reports, except that certain lithographic plates in the 11th report (1891) and 13th (1893) are omitted from the 45th and 47th museum reports.

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Report	*Price*	*Report*	*Price*	*Report*	*Price*
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14	1.00	18	.75	22	.40
15, 2v.	2.50	19	[.50]	23	.45
16	1.50	20	.50	[*See* Director's annual reports]	

Paleontologist's annual reports 1899–date.

See first note under Geologist's annual reports.

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Entomologist's annual reports on the injurious and other insects of the State of New York 1882–date.

Reports 3–20 bound also with museum reports 40–46, 48–58 of which they form a part. Since 1898 these reports have been issued as bulletins. Reports 3–4, 17 are out of print, other reports with prices are:

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7	.20	18 (" 64)	.20	28 (" 165)	.40
8	.25	19 (" 76)	.15	29 (" 175)	.45
9	.25	20 (" 97)	.40	30 (" 180)	.50
10	.35	21 (" 104)	.25	31 (" 186)	.35
11	.25	22 (" 110)	.25	32 (" 198)	.40
12	.25	23 (" 124)	.75	33 (" 202)	.35

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Botanist's annual reports 1867–date.

Bound also with museum reports 21–71 of which they form a part; the first Botanist's report appeared in the 21st museum report and is numbered 21. Reports 21–24, 29, 31–41 were not published separately.

Separate reports for 1871–74, 1876, 1888–99 are out of print. Report for 1900 may be had for 50c. Since 1901 these reports have been issued as bulletins.

Descriptions and illustrations of edible, poisonous and unwholesome fungi of New York have also been published in volumes 1 and 3 of the 48th (1894) museum report and in volume 1 of the 49th (1895), 51st (1897), 52d (1898), 54th (1900), 55th (1901), in volume 4 of the 56th (1902), in volume 2 of the 57th (1903), in volume 4 of the 58th (1904), in volume 2 of the 59th (1905), in volume 1 of the 60th (1906), in volume 2 of the 61st (1907), 62d (1908), 63d (1909), 64th (1910), 65th (1911), v. 2 of the 66th (1912) reports. The description and illustrations of edible and unwholesome species contained in the 49th, 51st and 52d reports have been revised and rearranged, and, combined with others more recently prepared, constitute Museum Memoir 4.

Museum bulletins 1887–date. 8vo. (1) *geology, economic geology, paleontology, mineralogy;* (2) *general zoology, archaeology, miscellaneous;* (3) *botany;* (4) *entomology.*

Bulletins are grouped in the list on the following pages according to divisions.
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Geology and Paleontology. 14 Kemp, J. F. Geology of Moriah and Westport Townships, Essex Co., N. Y., with notes on the iron mines. 38p. il. 7pl. 2 maps. Sept. 1895. *Free.*

19 Merrill, F. J. H. Guide to the Study of the Geological Collections of the New York State Museum. 164p. 119pl. map. Nov. 1898. *Out of print.*

21 Kemp, J. F. Geology of the Lake Placid Region. 24p. 1pl. map. Sept. 1898. *Out of print.*

34 Cumings, E. R. Lower Silurian System of Eastern Montgomery County; Prosser, C. S. Notes on the Stratigraphy of Mohawk Valley and Saratoga County, N. Y. 74p. 14pl. map. May 1900. 15c.

39 Clarke, J. M.; Simpson, G. B. & Loomis, F. B. Paleontologic Papers 1. 72p. il. 16pl. Oct. 1900. 15c.

Contents: Clarke, J. M. A Remarkable] Occurrence of Orthoceras in the Oneonta Beds of the Chenango Valley, N. Y.
—— Paropsonema cryptophya; a Peculiar Echinoderm from the Intumescens-zone (Portage Beds) of Western New York.
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Simpson, G. B. Preliminary Descriptions of New Genera of Paleozoic Rugose Corals.
Loomis, F. B. Siluric Fungi from Western New York.

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45 Grabau, A. W. Geology and Paleontology of Niagara Falls and Vicinity. 286p. il. 18pl. map. Apr. 1901. *Out of print.*
48 Woodworth, J. B. Pleistocene Geology of Nassau County and Borough of Queens. 58p. il. 8pl. map. Dec. 1901. *Out of print.*
49 Ruedemann, Rudolf; Clarke, J. M. & Wood, Elvira. Paleontologic Papers 2. 240p. 13pl. Dec. 1901. *Out of print.*

Contents: Ruedemann, Rudolf. Trenton Conglomerate of Rysedorph Hill.
Clarke, J. M. Limestones of Central and Western New York Interbedded with Bituminous Shales of the Marcellus Stage.
Wood, Elvira. Marcellus Limestones of Lancaster, Erie Co., N. Y.
Clarke, J. M. New Agelacrinites.
—— Value of Amnigenia as an Indicator of Fresh-water Deposits during the Devonic of New York, Ireland and the Rhineland.

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77 Cushing, H. P. Geology of the Vicinity of Little Falls, Herkimer Co. 98p. il. 15pl. 2 maps. Jan. 1905. 30c.
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New York State Museum

JOHN M. CLARKE, *Director*

THE SUSQUEHANNA RIVER IN NEW YORK AND EVOLUTION OF WESTERN NEW YORK DRAINAGE

BY

HERMAN L. FAIRCHILD

Smithsonian Institution
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New York State Museum
JOHN M. CLARKE, *Director*

THE SUSQUEHANNA RIVER IN NEW YORK AND EVOLUTION OF WESTERN NEW YORK DRAINAGE

BY

HERMAN L. FAIRCHILD

INTRODUCTION, HISTORICAL OUTLINE

The Susquehanna river is a very ancient stream with a very complex history. The story of its evolution in relation to land slope, continental movements and rock structure involves all the geologic history of New York since early Paleozoic time; while its present relation to the adjacent stream systems requires the description of the somewhat anomalous and puzzling drainage and physiography of all of central and western New York.

Four factors are chiefly concerned in the physiographic evolution of New York, namely: (1) climatic; (2) epeirogenic; (3) stratigraphic; and (4) glacial. The first of these factors is important, but is so indeterminate that it can not be seriously considered in this study. The second factor, the up-and-down movements of the continental surface, or land warping, has been active, but probably has not been a cause of diversion or change in the direction of stream flow, although it has probably influenced the stream gradients and rate of erosion. The most effective factor in the production of the present complex arrangement of the valleys of central and western New York has been the control exercised by the rock strata. To the varying resistance of the rocks to subaerial erosion, due to the variations in thickness, composition and structure in their vertical succession, must be attributed most of the striking features and the peculiar relationship of the valleys and stream directions.

The glacial factor produced radical changes in direction and volume of river flow and has partially obscured the preglacial topography. The glacial effects will be described in detail because they are the conspicuous features within the valleys, and the ones most available for educational work.

The lower or southern portion of the Susquehanna river, lying in Pennsylvania and in the Appalachian belt of deformed strata, was involved in the folding and lifting of the strata in Permian time, the "Appalachian Revolution." The rivers of that area were the subject of an admirable essay by W. M. Davis as long ago as 1889 (see number 5 of the attached bibliography). His analysis of the very difficult problem was so good that no extended paper on the genesis of the rivers of central Pennsylvania has been written since. This writing of Davis's may not be urged on the neophyte in earth science, but to the advanced student it is a most stimulating paper.

Above the west border of the Lackawanna-Wyoming coal basin the Susquehanna and its tributaries lie in relatively undeformed strata, but exhibit great diversion from the ancient, primitive flow, due to the factors already noted. The physiographic history of this upper section has not been written, and the present writing does not claim to exhaust the subject. Large elements in the drainage history, involving vast eons of time are as yet undiscoverable, and although more data may be found there will be elusive elements remaining in mystery. Some of the greater changes in the dramatic history which are fairly clear, or may be reasonably inferred, however, make a very interesting story.

The west branch of the Susquehanna, lying wholly in Pennsylvania, does not fall within the province of the New York survey. It was not greatly affected by glaciation, at least in the way of glacial obstruction, and has a history much more simple and uneventful than that of the north branch, (see the map, plate 1). This bulletin relates only to the north branch of the Susquehanna river, and particularly to the part above the coal region. Its upper waters and most of the larger tributaries are in New York, and it is thought that in late Tertiary time this drainage lay wholly in New York, with northward flow to the Ontario valley (plate 5). Several critical localities in the early life of the streams which were changed by the diverted and enlarging river lie in Pennsylvania, and our study can not be closely limited by state boundaries.

ERAS		PERIODS	CONDITIONS IN WESTERN NEW YORK
Cenozoic	Quaternary	Present	Continental erosion
		Pleistocene	Glaciation, with land depression and subsequent uplift
	Tertiary	Pliocene	Stages of continental uplift and continuous erosion
		Miocene	
		Oligocene	
		Eocene	
Mesozoic		Cretaceous	Erosion with peneplanation
		Jurassic	Erosion, with peneplanation, followed by uplift
		Triassic	
Paleozoic		Permian	Continental uplift; "Appalachian Revolution"
		Pennsylvanian	Area wholly land, with low elevation
		Mississipian	Only the southern border yet submerged
		Devonian	Slow rise of land, progressing from north to south; producing emergence
		Silurian	Oscillations of land; prevailing submergence in oceanic waters
		Ordovician	
		Cambrian	
Proterozoic		Several long periods	Conditions unknown
Archeozoic		Vast length of time	Conditions unknown

The above table, suggesting the probable physical conditions in central and western New York during the long periods of geologic time, and a brief foreword or outline of the complicated history will help the reader to follow and appreciate the story.

When central New York was permanently lifted out of the oceanic waters, in late Paleozoic time, the river had its birth. The flow was southward into the receding sea, which was yet lying over most of Pennsylvania. The great mountain-making revolution at the close of Paleozoic time apparently did not change the direction of flow in New York. The succeeding long Mesozoic era is supposed to have been, for this area, a time of subaerial erosion, and the rather uniform height of the higher hills has been interpreted as evidence of the Mesozoic peneplanes.[1] The Mesozoic stream history is unknown. Our oldest valleys are believed to date from Tertiary time, but perhaps were inherited from the Mesozoic stream courses (plate 4).

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[1] Davis's original spelling was "peneplain." But in emphasis of the theoretic geometric surface rather than of rocks, we now use "peneplane"; however, when speaking of the deposit or the topographic feature, the term "plain" is used; hence "near-plain."

In early Tertiary time the Susquehanna appears to have flowed southward into Pennsylvania by the present Tunkhannock valley, as suggested in plate 4. With continental uplift in Tertiary time, producing valley trenching with the rock control, the river was diverted, by "stream capture," to westward flow through Binghamton and Owego and with the excavation of the great Ontario valley the river was diverted northward through the Seneca valley, becoming a main tributary of the Ontarian river, with ultimate outflow to the Mississippi Valley.

A slight lowering of world climate produced continental ice sheets, and the advancing Quebec (Labradorian) glacier blocked the northward flow of the Susquehanna and other streams and forced it southward again. When the ice sheet overspread all of New York, all of the rivers were extinguished. With the waning of the glacier the river was recreated, by headward growth, following the receding south front of the ice sheet. But the southward channel, past Towanda, had been so deepened and the former northward channel, past Elmira, had become so filled with drift that the river has retained its southward course.

The enormous volume of the glacial river helps to explain the high-level and widespread gravel plains in the main and tributary valleys. Two other factors are concerned with the valley filling: (1) the barriers of drift left by the ice sheet, and (2) the lower altitude of the land when the glacier melted away. The quickened flow of the streams produced by the postglacial land uplift (figures 1 and 2) along with the removal of the drift dams has resulted in erosion of the plains and in valley fillings, producing the present valley topography.[1]

The history of the Susquehanna is too involved and complicated to be told as a continuous narrative, and the reader will find some repetition and overlapping in the following chapters. The earlier chapters, describing the evolution of the drainage, are necessarily somewhat technical; but the second part of the story, the Pleistocene or glacial history, will be found easier reading, and holding more of local interest.

In the prosecution of this study the writer has been placed under pleasant obligation to many friends; for automobile transportation to F. R. Pierce, Susquehanna, Pa.; I. P. Shepard, Waverly; Edwin Smith, Sherburne; Thur Smith, Newark Valley; and Paul LeHardy,

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[1] The glacial history of the river in Pennsylvania will be published by the Pennsylvania Geological Survey.

David Z. Morris, J. Foster Warner of Rochester. For critical reading of the manuscript and helpful suggestions thanks are due George H. Chadwick and Chris A. Hartnagel. Data relating to the depth of drift in the valleys have been supplied by the following professional drillers: Charles A. Daggett, Russell Shear and Peter Vanderhoff of Elmira; F. O. McIntyre, Owego; and Chester Thomas, Milan, Pa.

HYDROGRAPHY OF WESTERN NEW YORK

The map (plate 1) covers a wide area in order to show the indifferent relation of the Susquehanna to the other neighboring drainage systems. Some of the inconsistencies of the present drainage may be noted.

The upper stretch of the North Branch Susquehanna and its higher tributaries, and also the upper waters of the Delaware, have southward or southwestward flow, which is thought to be direct inheritance from the earliest drainage. The trunk stream flows southwestward to Harpursville (plate 17), south-by-east to Lanesboro (plate 16), northwest to Binghamton, west-by-south to Waverly (plates 11, 15), and then southeast, with meanders, to Pittston, Pa. This varied direction suggests radical changes from the original direction of flow.

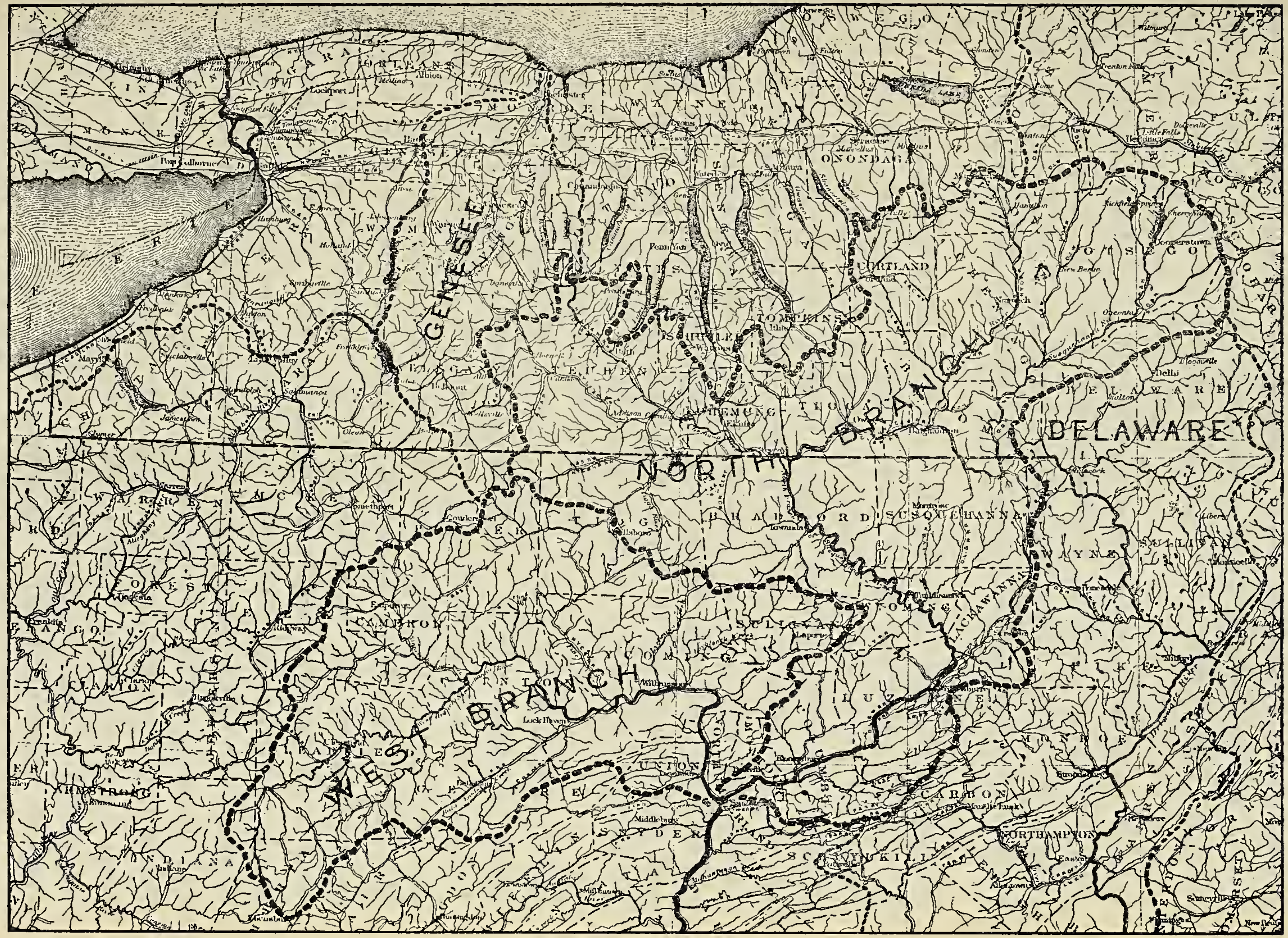
The tributary Chemung, from the northwest, receives the Tioga from the south. The Finger lakes all drain northward, but their combined outflow passes east to the Onondaga valley before it enters Lake Ontario by the Oswego river.

The West Branch Susquehanna gathers all its branches in a consistent dendritic manner for eastward flow to beyond Williamsport, where it turns south.

The headwaters of the Allegheny river flow northward into New York and then turn into southward flow, which is radical diversion from its preglacial flow (plate 5).

The Genesee river exhibits the most radical opposition to the primitive direction of drainage. Rising in Pennsylvania it flows north entirely across New York. It should be noted that the source of the Genesee river marks a locality of divergent flow. Streams head here for four distinct river systems: Genesee, Allegheny, and both the north and west branches of the Susquehanna. M. R. Campbell makes the center of his dome of the Harrisburg peneplane only about 30 miles west of the center of divergent drainage (map in 13).

It must be understood that the stream courses as they lie on the map are not sufficient basis for reading the drainage history, which requires for its full translation more geologic science than we possess today.



Drainage Areas of the Susquehanna River.

STRATIGRAPHY OF WESTERN NEW YORK

The stratigraphic geology of the Susquehanna drainage area in New York is comparatively simple. The rocks are all Devonian, unaltered shales and sandstones, except a narrow belt of the underlying Silurian at the headwaters along the Mohawk divide. All the strata have a small southerly dip.

Appalachian folding is represented in the Pennsylvania portion of the drainage area, in Tioga and Bradford counties, in eroded anticlines; but in New York the undulations, while easily recognized, are so moderate that probably they had no influence on the stream flow.

Any geologic map of New York will show that the upper Susquehanna waters east of the Finger lakes lie in Hamilton beds. All the rest of the New York drainage is practically in Upper Devonian, (Portage, Chemung and Catskill) strata. In Pennsylvania the river also lies in Upper Devonian until it reaches the west rim of the northern anthracite basin at West Pittston. Its western tributaries, in Tioga and Bradford counties, head in the high remnants of the synclines that hold the coal-mining districts of Blossburg and Barclay. On the east the Lackawanna river drains the anthracite valley through Carbondale and Scranton.

However, there is in the area a remnant of Mississippian (Subcarboniferous) strata of much significance. In the southeast corner of Susquehanna county, Pa., the Elk hills stand high above the general surface. The north knob has altitude of 2684 feet (plate 9) and is capped with Pocono sandstone. Eastward, in Wayne county, the Pocono beds cap a series of high hills which are the continuation of the Moosic mountain, the northward extension of the hard basal rocks of the Lackawanna syncline. The north and south knobs of the Elk hills along with Ararat and Sugar Loaf and other hills of the Moosic range are monadnocks, rising above the irregular surface of the peneplane, being only remnants of hard, superior beds which once covered the whole region. The present significance of these Pocono outliers is the evidence which they give that Mississippian strata originally extended far northward. The occurrence of these beds in remnants of synclines in Bradford and Tioga counties and in northwestern Pennsylvania, also in southwestern New York, indicates that Pocono sandrock once covered all of northern Pennsylvania and some unknown extent of southern New York.

The Elk hills give us the minimum of land erosion in the region. Plate 9 and figure 3 show the relief. The North Knob is recorded as 2684 feet above tide. The higher points of the region, in Catskill sandstone, suggest a peneplane at about 2100 feet, which implies a general erosion of nearly 600 feet since the Appalachian uplift. The Tunkhannock valley on the line of the profile (figure 3) and less than 6 miles west of the North Knob, has altitude of only 900 feet. At South Gibson, 4 miles northwest of the knob the valley bottom is 1000 feet. This gives a depth of stream erosion beneath the old peneplane of 1100 feet. This Tunkhannock valley was the channel of the Susquehanna river at the beginning of Tertiary time, as will be shown later in this bulletin.

PHYSIOGRAPHIC HISTORY OF WESTERN NEW YORK

The highland in New York which carries the Susquehanna drainage, now 2000 to 2500 feet above ocean, was sea bottom during Devonian time. The long and varied history previous to the Devonian does not concern the present story, except as to character of the rocks, which will be noted later. Some conception of the ups and downs of the continental surface may be had by study of Schuchert's maps of the ancient geography (21).

It appears that a belt along the south border of western New York was still submerged in Mississippian time, but that in Pennsylvanian (Coal measures) time all of the State was above the sea. All of the drainage of the New York area during Paleozoic time appears to have been southward, from the uplifted old land of Canada, across New York into the receding interior (epicontinental) sea. The present stream lines between the Hudson valley on the east and the Finger lakes area on the west are doubtless an inheritance from that ancient southward drainage.

Since that primitive stream flow was established, across New York from Canada, it has been affected by at least two periods of great continental uplift, and one epoch of overwhelming continental glaciation. The first great uplift was the Appalachian Revolution, in Permian time, closing the immensely long Paleozoic Era. The thick sediments in Pennsylvania were mashed and folded into a huge mountain system stretching from New York to Alabama. In New York this great disturbance of the earth's crust was relieved by bodily lifting, without much crushing or folding, producing the broad and high Allegheny plateau. A few of the crustal folds of northern Pennsylvania are continued into New York as weak anticlines and synclines, but the elevation of the plateau in New York was probably sufficient to keep the enlivened or rejuvenated streams in their southward courses. Possibly the folding of the strata in Pennsylvania was so slow that some rivers even there kept their right of way, as "antecedent" streams.

Succeeding the Appalachian mountain-making, with its relief of strain in the earth's rind, came the long era of the Mesozoic during which the continent appears to have had two long periods of standstill or relative rest from violent epeirogenic movements. Whatever mountains were pushed up into the air during Permian time by excess of uplift over erosion, are believed to have been planed away by the destructive atmospheric forces during the long Triassic-

Jurassic and Cretaceous standstill. The result was a vast plain of erosion, or near-plain, sloping gently to the sea.

The level-topped ridges of hard sandstone which constitute the bold, parallel mountains of New Jersey, Pennsylvania and southward, are regarded as remnants of that ancient but now uplifted and wasted peneplane surface, the weaker, less resistant strata having been eroded away to produce the intervening valleys. This near-plain has been named from the even-crested ridges and called the "Kittatinny," etc., but as it had its finishing touches in Cretaceous time it will be spoken of here as the Cretaceous peneplane. [1]

The Cretaceous peneplane appears to have extended over all of the Susquehanna territory, and probably more widely. Probably the streams were mostly held in their old courses in the lowering land surface with diminishing slopes. The oldest valleys in central and western New York indicate a direction of stream flow to south and southwest, as shown in plate 4. Some of these ancient valleys certainly antedate the present river valleys, and they may date as far back in time as the Cretaceous.

The very thick and weak shales of the Ordovician and Silurian along the belt of the present Mohawk and Ontario valleys encouraged the production of the latter as "subsequent" valleys, by the deepening of the east and west tributary streams. It is possible that these great, dominating valleys were initiated during Cretaceous time, but their great development quite certainly dates from Tertiary time.

Following the long standstill, with erosion and base leveling, of Cretaceous time came the second long epoch of continental uplift, in Tertiary time. It is probable that the great rise in the Tertiary was not a unit or single lift, but by a series of steps with long erosion intervals, and possible peneplanation, and possible oscillations. In the present study the manner and time of the Tertiary uplift is not of primary importance, but the fact of great recent uplift, and probably much greater elevation than we have today, is the important event in the stream history. With the uplift the streams were revived and deeply intrenched their valleys in the elevated peneplane (Allegheny plateau), giving us the present remarkable topography, with its high relief and anomalous drainage. The enlivening of the drainage and the valley deepening gave effect to the varying resistance of the rock strata, which produced diversion even of trunk streams. Tributary and subsequent streams which happened to be fortunately situated in weak rocks or along the strike of the strata deepened their channels more rapidly, and by headward erosion tapped and captured adjacent drainage. In such manner the primitive Susquehanna was diverted from its southward course into its westward course from Lanesboro, Pa., to Waverly, N. Y. (Compare plates 4 and 5), and the great Ontario and Mohawk valleys were produced by the union of east and west tributaries of the primitive south-flowing trunk streams.

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[1] Some students question the date of the Kittatinny peneplane, especially E. W. Shaw, in paper 23 of the attached list. A review of the literature on peneplanes is there given.

Only yesterday, speaking in geologic terms, the development of the Tertiary drainage was interrupted, forced south, and finally entirely quenched in New York by burial under the Quebec (Labrador) glacier. And when the ice sheet was removed the old valleys were so effectively blocked in places by the glacial drift that the rivers had to cut new channels. The radical changes in the river course may be seen by comparing plates 1 and 5.

TOPOGRAPHY OF WESTERN NEW YORK

The territory involved in this study, and also that of the West Branch, is a part of the great Allegheny plateau, the Catskill mountains surmounting the high eastern front. The altitudes and the slopes of the land surface, however, are poorly indicated by the maps of drainage.

The great changes which have taken place in the altitudes of the rocks and of the land surface may be appreciated by two examples. Rocks in southern New York and northern Pennsylvania which were in the sea near the end of Paleozoic time are now 2000 to 2684 feet above the sea. Conversely, the bottom of Lake Ontario, which must have been at least a few hundred feet above the sea in Tertiary time in order to permit of the flow of the Ontarian river which excavated the valley, is now about 500 feet below sea level.

The Catskill mountains, the highest points more than 4000 feet above tide, are supposed to be remnants of a Jurassic peneplane, while the Cretaceous peneplane is represented in central and southwestern New York by an intrenched plateau averaging about 2000 feet, with points yet higher.

The headwaters of the Susquehanna and its upper tributaries lie in cols (notches or saddles) along the divide between the drainage area of this river system and that of the Mohawk and the St Lawrence.

The following tables give the altitudes and the relief along the principal streams. The figures show feet above tide, being mostly taken from the topographic maps. The figures for the high points or land summits refer to the highest points of the neighborhood, or within a few miles. As the Cretaceous peneplane is about 2000 feet elevation, or perhaps 2100 eastward, the points much above that figure probably represent unleveled masses, "monadnocks," or remnants of the preceding Triassic-Jurassic plane. The figures for the headwaters are for the cols of the lowest of the principal twigs of the drainage. The figures for erosion are suggestive of the minimum intrenching by the streams.

TABLE I

Altitudes at heads of upper tributaries of the Susquehanna river

	Tioughnioga	Otselic	Chenango	Unadilla	Susquehanna	Cherry Creek	Schenevus	Charlotte
High land.........	2 115	2 160	1 720 1 920	1 900 1 960	1 880	2 301	2 427	2 473
Col at headwater...	1 300	1 640	1 150 1 240	1 260 1 220	1 360	1 400	1 500	2 140
Minimum erosion . .	815	520	571 680	640 740	520	901	927	333

TABLE 2

Altitudes at different localities on the north branch of the Susquehanna river in New York

	Otsego Lake	Milford	Oneonta	Otego	Unadilla	Sidney	Bainbridge	Harpursville	Windsor	Susquehanna	Great Bend	Binghamton	Union	Owego	Nichols	Waverly
High land	2 200	2 300	2 200	2 040	2 000	2 000	1 700	2 021	1 940	.....	.....	1 820	1 760	1 642	1 556	1 697
River	1 194	1 160	1 070	1 050	1 000	980	970	950	900	875	860	830	800	790	770	755
Minimum erosion	1 006	1 140	1 130	990	1 000	1 020	730	1 071	1 040	.....	.....	990	960	852	786	942

In Pennsylvania

	Sayre	Athens	Ulster	Towanda	Standing Stone	Rummerfield	Wyalusing	Laceyville	Meshoppen	Mehoopany	Tunkhannock	Falls	Pittston	Wilkes-Barre	Sunbury	Harrisburg
High land	.....	.....	.....	.....	.....	.....	.....	.....	.....	2 300	2 200	1 600	1 700	2 100	1 300	1 300
River	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	570	540	530	430	290
Minimum erosion	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1 030	1 165	1 570	870	1 010

TABLE 3

Altitudes at different localities on the Chenango river

	Morrisville	Randallsville	Earlville	Sherburne	Galena	Norwich	Oxford	Greene	Chenango Forks	Chenango Bridge	Binghamton
High land	1 700	1 700	1 900	1 900	1 865	1 960	1 886	1 584	1 706	1 600	1 820
River	1 270	1 100	1 080	1 050	1 020	1 000	960	900	885	865	830
Minimum erosion	430	600	820	850	845	960	926	684	821	735	990

TABLE 4

Altitudes on the headwaters of the Chemung river system

	Bennett	Canadea	Canisteo (head)	Canisteo (Burns)	Cohocton (Wayland)	Twelvemile	Fivemile	(Bath divide)	Mud Creek (Little Lake)	Meads Creek	Post Creek	(Horseheads divide)	SOUTHERN TRIBUTARIES			(Tioga village)
													Cowanesque	Crooked	Tioga	
High land	2 200	2 340	2 220	2 000	2 140	2 163	2 110	1 880	1 680	2 034	2 034	1 647	2 540	2 272	.....	2 284
Stream head	.....	2 100	2 080	1 200	1 380	1 500	1 460	1 140	1 120	1 480	1 280	910	2 120	1 170	2 000	1 030
Minimum erosion	.....	240	140	800	760	663	650	740	560	554	754	737	420	1 102	.....	1 254

TABLE 5

Altitudes at different localities on the Cohocton-Chemung system

	Wayland (Col)	Cohocton	Wallace	Avoca	Kanona	Bath	Savona	Campbell	Painted Post	Corning	Big Flats	Elmira	Wellsburg	Chemung	South Waverly	Athens
High land	2 140	2 155	1 923	1 966	1 950	1 880	1 900	1 920	1 800	1 905	1 800	1 780	1 845	1 706	......	......
River	1 380	1 280	1 220	1 180	1 140	1 100	1 040	1 000	930	910	900	860	800	780	......	......
Minimum erosion	760	875	703	786	810	780	860	920	870	995	900	920	1 045	826	......	......

TABLE 6

Altitudes at heads of tributaries between Binghamton and Elmira

	Nanticoke	Owego (East branch)	Owego (West branch)	Wilseyville	Cattatonk	Cayuta	Wyncoop	Baldwin	Newtown
High land	1 600	2 028	2 009	1 895	1 800	2 000	1 863	1 753	1 872
Lowest col at headwater	1 320–1 400	1 207	1 280	1 000	1 050	1 140	1 320	1 150	1 400
Minimum erosion	280–200	821	729	895	750	860	543	603	472

PRIMITIVE DRAINAGE OF WESTERN NEW YORK

Plate 4

In spite of the radical changes in drainage produced by the several modifying factors acting through many millions of years, with deep erosion and lowering of the area, it appears that a number of valleys have retained or inherited the courses of the earliest drainage. This is most evident in the region of the hard, quartzose, Catskill rocks, in the area drained by the upper Susquehanna and the upper Delaware (plate 4). There can be little doubt that the present streams have the same general direction as the original (consequent) drainage. The opposite extreme is found in the Mohawk, Ontario and Erie basins, where the very deep erosion has destroyed every vestige of the earliest stream flow. In the district south of the Finger lakes and over the upper Genesee valley, where the land degradation has been only moderate, a number of wide, elevated and abandoned valleys with southwestward trend suggest very ancient stream direction (plates 3 and 4).

The earliest (consequent) streams in the western half of New York must have accompanied the first permanent rise of the area out of the interior (epicontinental) sea. The succession of rock strata shows that the progressive land uplift was in general direction from north to south. The vertical oscillations of western New York during Paleozoic time, producing a long succession of marine submergencies and subaerial exposures, have been pictured in a series of paleogeographic maps by Professor Charles Schuchert (21). These maps show that the relation of the rising and exposed land to the receding sea would cause the rivers in western New York to flow in southwestward direction. According to these maps the Adirondack area and the district east of the Ontario basin were permanently raised above the sea in Upper Ordovician time (Schuchert's plate 61), with the oceanic waters on the southwest. But the area south of the Adirondacks and the Ontario basin area, after several burials in the sea with long intervals of exposure, was not permanently lifted above the sea until the close of Devonian time (Schuchert's plates 77-78).

It has already been shown that the remnants of Pocono sandrock on the summit of the Elk hills in northeast Pennsylvania, only 15 miles south of the New York line, indicates that at least the southern border of the State, in the Binghamton district, was submerged in early Mississippian time. The occurrence of Pottsville conglomerate in the southwestern part of the State shows either submergence or very low altitude in Pennsylvanian time (Schuchert's plates 83-84). And during all that ancient time down to at least the Permian the oceanic waters were contiguous on the south, and consequently the drainage of New York must have been south to southwestward across the State.

At the time of that earliest permanent uplift of western New York there was no Ontario basin nor Mohawk valley. The rivers had their sources in Canada and flowed southward, carrying the waste of the exposed land into the receding sea. As the land uplift progressed the rivers extended their courses over the newly-exposed marine deposits, and finally passed entirely across the State into Pennsylvania.

Any hypothetic map of that primitive, Paleozoic drainage would be only a series of lines from Canada southwestward across the western part of the State, and no such map is presented. Plate 4 shows the oldest drainage lines for which evidence is found in the present topography, and the valleys marked by these lines may not be older than late Mesozoic or early Tertiary, although they might have been inherited or intrenched from Paleozoic stream courses. Such inheritance is thought to be the fact for the upper Susquehanna and upper Delaware. The strata of the region are nearly horizontal and fairly uniform over wide extent. No folding of the beds has been sufficient to produce any diversion of the streams. Minor oscillations of the land level occurred during the deposition of the strata, and great changes of level have occurred since the primitive rivers were established; but the uplifts of Permian and of Tertiary time raised the whole region bodily, or as a unit, without causing change in the general direction of stream flow. The upper Delaware and the upper Susquehanna with its upper tributaries are quite surely in their original courses. They have probably merely intrenched their valleys as they were rejuvenated by the continental uplifts.

The northeast by southwest direction of a number of old valleys in the area west of the Susquehanna district above described is significant in this connection. They have been noted at the beginning of this chapter. Some of these wide, old valleys now carry no streams, or only weak and inconsequential ones. They are transverse to the present lines of drainage and are evidently of much greater age than the present master-stream valleys. Only the more conspicuous valleys of this kind are shown in plate 4, but the net of transverse and discordant valleys is shown in plates 2, 3 and 5. Unfortunately two considerable areas in the southwest part of the State are not yet covered by the topographic sheets, or the number of these southwestward lines could be increased.

These old valleys having the direction of ancient stream flow may be divided into three classes: (1) those which still carry streams; (2) those which are practically abandoned by streams; and (3) those in which the stream flow has been reversed. The first class includes the Delaware and Susquehanna valleys, already described, and also numerous shorter valleys or sections of valleys on the west. The second class includes the most puzzling element in New York physiography, the broad, elevated, "hung up" valleys which are not now occupied by effective streams, and in portions by streams of reversed direction. Some attempt was formerly made to explain these "hanging" valleys by glacial erosion of the intersecting ones. These old valleys are themselves, however, more nearly in line with the direction of glacial flow than are the deeper valleys which cut across them. The old drainage lines shown in plate 5 include both the second and third classes, and should be studied in connection with the topographic sheets.

The few exceptions, in the higher ground, to the southwestward direction of the larger valleys are the head waters of the Genesee trunk, but not its tributaries; the Canisteo; the Cohocton-Chemung; and the Cayuta, Catatonk and Tioughnioga. The upper Genesee is reversed (obsequent) Tertiary flow, and the other valleys owe their size and importance if not their origin to forced glacial drainage, as will be described later. The Ontario basin has been lowered by some thousands of feet. The drainage is Tertiary, largely reversed (obsequent), and will be the subject of a later chapter.

On the Canajoharie, Richfield Springs and Winfield sheets it is seen that the line of water parting between the Mohawk and the Susquehanna drainage lies some miles north of the higher ground, and some hundreds of feet lower. The precise divide has been established by the resistance of the combined limestone beds of the Helderberg and the Onondaga, while the higher ground on the south is Hamilton shale. This relationship of the topography to the drainage may have little significance as to the relative age of the valleys, but the south-leading valleys must antedate the Mohawk depression. The prominent notches across the divide and at the heads of the Susquehanna drainage are believed to represent river flow from the Adirondack area before the Mohawk valley was initiated.

A careful examination of the valleys on the north side of the Mohawk depression will show a reasonable connection or relationship in direction between some of those valleys and the upper valleys of the Susquehanna system. This is not attempted in plate 4.

CONDITIONS IN MESOZOIC TIME

Between the date when the primitive southward drainage was established in western New York and the time represented by the drainage shown in plate 5 lies a vast interval of tens of millions of years, much of which is in mystery. This includes all of the Permian Period, the long Mesozoic Era, and most of the Tertiary Period. In physical changes this immense duration covers the great Appalachian Revolution, with its long epoch of mountain-making, the destruction of the mountain ridges by subatmospheric erosion and the supposed reduction of the area under study to a near-plain, then the uplifting of the area in Tertiary time, with the rejuvenation of the streams and some diversion of their courses.

The changes in drainage effected by the more recent, or Tertiary, uplift will be considered in the succeeding chapters. The larger part of the history, during Permian and Mesozoic times, is quite unknown, and here is the chapter in the dramatic story where we must appeal to imagination and theory.

The first serious interference with the primitive drainage must have been the Permian uplift. Then the Atlantic border region was pushed to the northwest some 15 miles, producing the crushing, crumpling and folding of the Paleozoic sediments, as shown in the Appalachians. Some of the deep-seated material of the earth's rind, in the plastic zone beneath the belt of folding, appears to have been pressed northwestward in beneath the less folded belt, producing the bodily uplift of the Alleghany plateau. This plateau uplift must have been sufficient to preserve the superior elevation of the upper Susquehanna area, as the streams appear to have preserved their southward courses into Pennsylvania.

The immediate effect on the rivers in Pennsylvania of the surface folding in the Appalachian belt is a difficult but interesting problem (see Davis' paper, No. 5). If the ridges rose so slowly that the Susquehanna and other transverse streams kept their right of way and cut "water-gaps" across the ridges then we should call the rivers "antecedent." This would be the simplest, but probably not the true, explanation of the transverse relation of the Delaware, Lehigh and Susquehanna rivers to the folds. The alternative explanation attributes the river courses to adjustment and diversion during the Mesozoic peneplanation and the Tertiary uplift. If the Susquehanna was diverted by the Permian uplift, however, it should have swung southwestward, parallel to the folding, and it is difficult to imagine how it could ever have been thrown back across the mountain belt. It is reasonable to assume that the trunk streams in New York at least retained their general direction during Permian and Mesozoic times, and that the serious diversions took place in Tertiary time. The more difficult and elusive history of the drainage in Pennsylvania is not strictly a part of the present study.

During Mesozoic time it is supposed that our New York area was suffering continuous erosion during two stages of peneplanation and was eventually reduced to a low, rolling surface graded to sea level. Beyond this we have no idea of the details in the history.

The higher hills in any district of western New York have such a general correspondence in altitude that from elevated viewpoints the horizon is a remarkably smooth and level line. This fact is the chief argument for the peneplanation theory. In casual examination of one of the topographic sheets of a hilly country the correspondence in height of the higher hilltops may not be evident. The differences in height must be compared with the total elevation. Some idea may be had by averaging the high points given in preceding tables (pages 16–19) and comparing the variations with this average altitude. The best illustrations of the peneplane is found in the even-crested mountain ridges of Pennsylvania, in the Harrisburg district, for example.

It does not appear likely that there could be serious change in the courses of the rivers during the Mesozoic peneplanation. The stream gradients were decreasing and the causes of diversion were less effective. It appears probable that the drainage at close of the Cretaceous was similar in direction to that at the close of the Permian. Plate 4 is perhaps a map of Cretaceous valleys.

DRAINAGE ADJUSTMENT IN TERTIARY TIME

Mohawk Valley; Susquehanna River Beheaded

With the above discussion of the physiographic history of the area we must now try with the help of the scientific imagination to visualize the events or changes by which the Susquehanna-Tunkhannock river of more ancient time became the great Susquehanna-Senecan river of late Tertiary time.

The original Susquehanna had its source, and its upper tributaries somewhere in the Adirondack district. It was beheaded, or its upper waters cut off, by the creation of the Mohawk valley. The date of this accident to the Susquehanna is not precisely known. Most physiographers assign the Mohawk valley to the Tertiary period, which must certainly be true for the larger part of the erosion. This valley is subsequent to the Hudson, so that the question of age may relate primarily to the Hudson. For our present purpose the precise date, whether late Mesozoic or early or middle Tertiary, is not essential.

As the Mohawk valley is wholly erosional, being carved out of Paleozoic strata with only moderate dip, it is evident that the higher strata on the south side of the valley once extended northward to and perhaps over the southern Adirondacks. A great thickness of relatively weak rocks encouraged the headward growth of the initial Mohawk along the strike of Ordovician shales until it had extended its domain northwestward and captured the headwaters of the Susquehanna that had been flowing southward across the territory. It has already been suggested that study of the stream valleys north of the Mohawk may enable the student to correlate those valleys with the present Susquehanna headwaters.

Except the Schoharie creek the southern tributaries of the Mohawk are very short. The Oriskany and Sauquoit creeks belong essentially to Ontario drainage, because the preglacial head of the Mohawk appears to have been at Little Falls. The present divide, at Rome, has been established by glacial interference. The south wall of the Mohawk valley is relatively steep and narrow, suggesting a southward migration of the valley; and some cols are not in the line of the high ground of the general divide, but lie somewhat northward, on the south wall of the valley, being determined by the hard limestones as already noted.

Westward Diversion of the Susquehanna

The maps show a radical change in the direction of the river after it enters Pennsylvania. At Lanesboro and Susquehanna villages the river makes an abrupt turn from south to west and northwest. This long ago gave suggestion of an abandoned channel south of Lanesboro. In 1908 the writer examined the district and found the old channel marked by a deep notch or "wind gap" across the divide. This pass is at the Rosskelly four corners, 5 miles south of Lanesboro, and in Jackson Township, and is the col at the heads of the north-flowing Canawacta and the south-flowing Tunkhannock creeks. The pass has been swept by glacial waters, the outflow of a glacial lake in the Canawacta valley. A well-marked bowlder-strewn channel leads south from the road corners (plate 26). The width of the channel is estimated at about 400 feet, but the valley proper is one-fourth of a mile wide and the hills rise 400 or 500 feet above the pass. The altitude is given by I. C. White (2, page 18) as 1600 feet. Three aneroid measurements at different times from distant benches have made it 1540, 1535 and 1568.

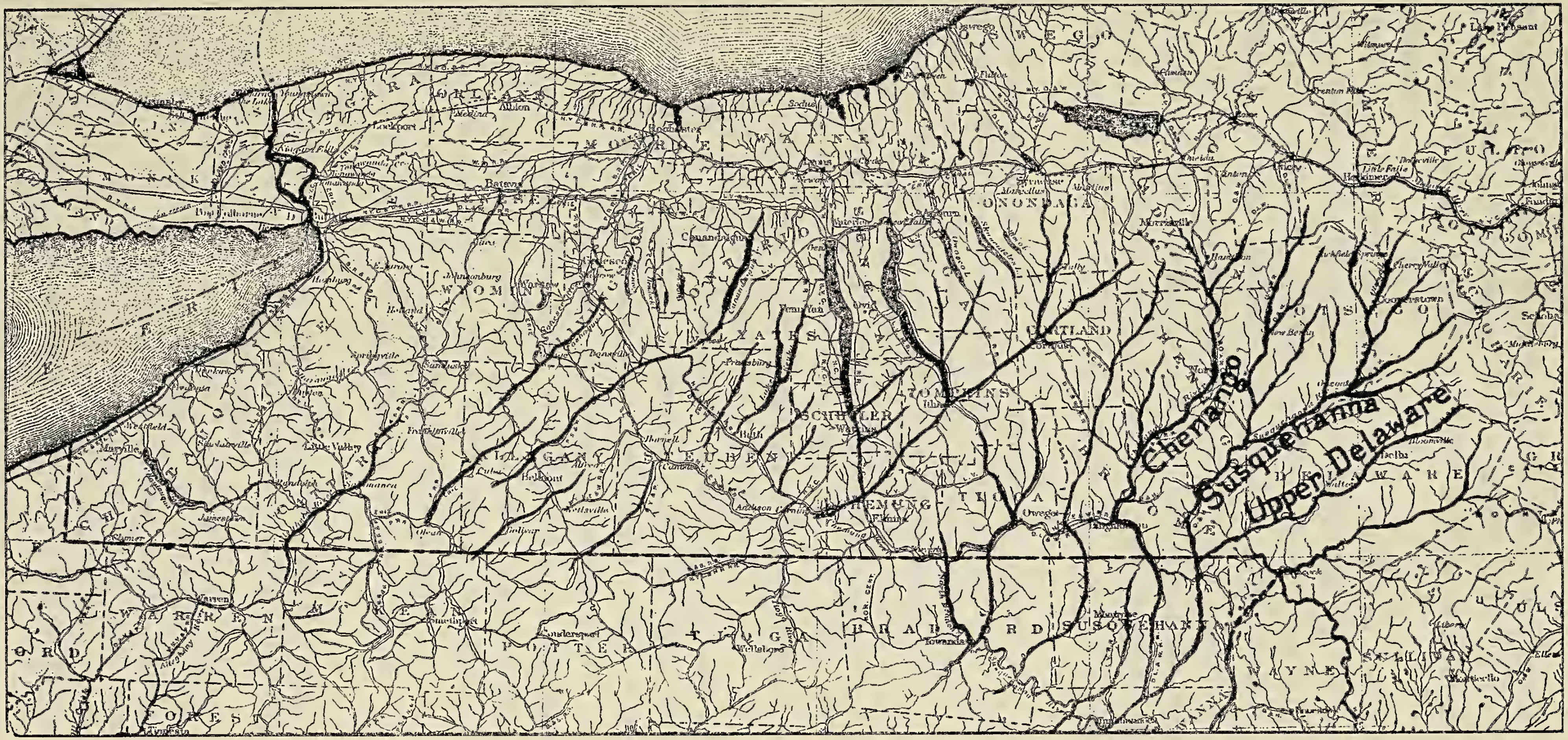
The Tunkhannock creek, heading at this col, flows southwest and enters the Susquehanna river at Tunkhannock village. The great viaduct of the Delaware, Lackawanna & Western railroad crosses this old course of the ancient Susquehanna river at Nicholson (plate 27).

We have no topographic map of the quadrangle covering the Jackson wind gap but fortunately the adjacent sheet on the south is published, the Dundaff sheet (plate 9), which shows 10 miles of the Tunkhannock valley, from above South Gibson to near Nicholson. This sheet also covers the Elk hills, capped with Pocono sandstone, at an elevation of 2684 feet. This summit is only 4 miles from South Gibson, where the Tunkhannock creek has an altitude of 1000 feet. The original extent of the Pocono beds has been noted, and it is certain that the valley trenching at South Gibson has removed at least 1684 feet of hard Catskill and Pocono.

Reference to plate 5 shows that the upper Delaware was a tributary of the Susquehanna, joining the latter just south of the state line. The present divide between the two rivers is at Gulf Summit, where the Erie railroad found the lowest pass from the Susquehanna valley over to the Delaware.

This map also shows three parallel south-flowing rivers west of the Susquehanna, being the Chenango river, the Nanticoke creek joined with the Otselic creek, and the two branches of the Owego

Plate 4



Courses of Very Ancient Drainage as Suggested in the Existing Valleys

creek. Of course this mapping is hypothetic, but it has good basis. The greatest uncertainty relates to their southern courses, in Pennsylvania. Today they are branches of the west-flowing stretch of the Susquehanna.

As the Jackson wind gap is a relic of the southward flow of the ancient Susquehanna, so the southward continuation of the ancient Chenango river is probably marked by the notch in the divide, 2 miles southwest of New Milford, Pa., and 6 miles northeast of Montrose. The low pass is utilized by the Delaware, Lackawanna & Western railroad for its main line between Scranton and Binghamton. In his study of Susquehanna county for the Second Geological Survey of Pennsylvania, Dr I. C. White noted this pass and described it as follows:

> In Susquehanna county there are two or three instances in which streams are now flowing in opposite directions, with their heads at a very low divide in the floor of probably ancient waterways.
>
> One of these is the old valley in which Martins creek flows southward and Salt Lick creek northward. The divide between the two streams is a low drift deposit in a comparatively narrow valley, 500 feet below the general level of the uplands (2, page 28).

On pages 105–106 of the same report Doctor White again refers to this pass. He gives the altitude as 1175 feet.

The map (plate 4) shows two other ancient rivers west of the Chenango with similar southern drainage. One of these is made of the present Otselic and Nanticoke creeks north of the present Susquehanna, and the Choconut-Wyalusing creeks south of the Susquehanna, and crossing the latter at Union between Binghamton and Owego. The other hypothetic stream ties together the two branches of the Owego creek in New York and the Apalachin creek in Pennsylvania, crossing the Susquehanna at Owego.

Doctor White did not fail to recognize these two passes. In his report (2) he says:

> At the heads of Choconut and Apalachin creeks similar low, drift-filled divides are seen separating their waters from those that go southward into the Wyalusing (page 29).
>
> Near the southern line of this area (Apalachin township) there is a low divide between the head waters of the Apalachin and those streams which carry the drainage southward and southwestward into the Wyalusing; here the aspect of the country looks very much as though the northern ice sheet had cut down the divide to such an extent that the morainic drainage may have passed southward across it into the Wyalusing valley (page 81).

The writer has visited the passes described above and finds that Doctor White's suggestion of glacial drainage across the cols was based on good observation, for they carried the waters of local glacial lakes. The divide between the north-flowing Choconut and the south-flowing Wyalusing creeks is near St Joseph's Church, about 3 miles east of Friendsville, Susquehanna county, Pa., with aneroid altitude of 1275 feet. This is in a notch about 400 feet deep, and is a swamp col that was the outlet of the Choconut glacial lake.

The divide between the Apalachin creek and the north branch of the Wyalusing is at "Bear Swamp," 2½ miles northwest of Friendsville, in a deep, narrow, dark valley, about 1225 feet by aneroid, and between hills rising at least 600 feet. This is also a swamp col, and was the outlet for the Apalachin glacial lake.

The general process by which these three south-flowing rivers, and the Susquehanna as a fourth, were dissected and the upper waters thrown into westward flow is quite evident and was effected in a similar manner to the capture of the upper waters of the Susquehanna by the Mohawk, and their diversion to eastward flow, so these four rivers were beheaded by a stream developed from east-and-west tributaries lying along the south border of the State, and which had cut down into the weak Chemung shales, lying beneath the hard Catskill sandstone. Between the Chenango and the Susquehanna the operation is clear. The abandoned Jackson pass is now at least 1550 feet. The New Milford pass, the path of the old Chenango, is about 1175 feet, or 375 feet lower. A west-flowing tributary of the Chenango, with its greater fall, had advantage over any opposing tributary of the Susquehanna. By headward erosion the former eventually tapped the Susquehanna and added its waters to the Chenango, or to whatever waters had previously captured the Chenango. By similar diversion all the south-flowing streams between Lanesboro and Waverly were turned westward.

We can not be sure of the order in time of the capture and westward diversion of the rivers, especially because we do not know where the most western control was located. The greater Susquehanna with its glacial flood has deepened its path; and we have no Pennsylvania topographic sheets of the wide area involved until within 15 miles of Pittston.

It is possible that the beheading process began on the west and progressed eastward, and that the Susquehanna was the last capture. One reason for this thought is that the Martins creek valley, the old path of the Chenango, is not as capacious as that of the Tunkhannock, the path of the original Susquehanna. Another point is that the cols east and west of Friendship are higher than the New Milford pass, while the divides at Montrose and all other passes are still higher. The result of the stream changes, however, is more important than the exact sequence.

Another interesting problem is the date in geologic chronology when the westward diversion of the Susquehanna occurred. Undoubtedly it represents a lively rejuvenation of the general drainage, and this, of course, implies an uplift of the wide region. If the even skyline of the high ground represents a peneplane of the Mesozoic erosion, then surely this stream diversion was Tertiary, and probably in early Tertiary. It most certainly was the continuing effect of the earliest land uplift succeeding the peneplanation of the Allegheny plateau.

We have a suggestion of relative duration in the three episodes of erosion, the two relating to shifting drainage and the previous peneplanation. In the district of Jackson pass the high ground supposed to represent the Cretaceous peneplane averages about 2100 feet in altitude. The Elk hills, close by, rise to 2684 feet, and are apparently a monadnock in the old plain. This gives at least 584 feet for the Cretaceous erosion, in hard Pocono and Catskill sandstones. At the Jackson gap the old Susquehanna river intrenched its channel in the Catskill sandstone of the peneplane about 550 feet (2100–1550) before its diversion. At the village of Susquehanna the present river is about 890 feet, hence since the diversion the river has intrenched about 660 feet, partly in Chemung shales. This later erosion includes the scouring by the first glacial flood. Using round numbers we have about 600 feet of general land erosion, nearly the same for the valley cutting in Catskill sandstone by the Susquehanna before its diversion; and something more than 600 feet of downcutting in partly weaker rocks since the diversion. The Cretaceous peneplanation represents vastly greater time than the valley trenchings.

Ontario Valley; Reversal of Primitive Flow

The primitive (consequent) drainage across the Paleozoic coastal plain which occupied the entire area of the present Ontario basin must have been southwestward toward the retreating Mississipian sea. This stream work began as soon as the area was exposed to the atmosphere, perhaps in mid-Devonian or later Devonian time.

All traces of this early drainage has been destroyed by the deep erosion of the strata over all of central and western New York. In plate 4 no attempt has been made to indicate that ancient stream direction, which could only be suggested by arbitrary lines drawn from Canada across Lake Ontario and western New York. The courses of the Genesee river and the valleys of the Finger lakes may have no definite relation to the early drainage.

The physical changes over the western part of the State from that hypothetic, consequent drainage down to the time of the Preglacial drainage, shown in plate 5 are unknown, yet this interval covers the vast geologic time from the Devonian to the late Tertiary. We see the final result of the great oscillations in the altitude of the continent and of the changes in the drainage in the present gross topography and the larger stream valleys, but the long and complex process is in mystery.

The wide Ontario valley is the great positive topographic feature of the western part of New York, and it became the dominating factor in the stream flow. A full discussion of its origin will involve a discussion of the origin of the basins of all the Great lakes, or the preglacial history of the St Lawrence river system, which is one of the unsolved problems in American geology; and such study is not intended in this writing.

We know that rivers are the valley makers, and it is certain that the Ontario basin is a valley of erosion, carved out of the thick and weak Ordovician and Silurian strata by atmospheric agencies. Recent land warping and northward uptilting may partly account for the lake, or the basining, but not for the valley. The reader may find it difficult to realize that the deep valley, with the bottom of Lake Ontario now almost 500 feet below sea level, was excavated by a land stream flowing to the sea. Yet this is a small example of the up-and-down (epeirogenic) movements of the continental surfaces. The thickness of the oceanic sediments beneath the city of Rochester is quite 3100 feet, the lowest rock being sandstone, a shallow-water deposit. This proves a net subsidence of about 3000 feet. A thickness of at least 1000 feet of marine sediments has certainly been eroded from the locality, which makes the subsidence at least 4000 feet. The subsequent net elevation has been the thickness of the strata removed plus 500 feet, the present elevation of the place where the deep boring was made, or 1500 feet. It appears probable that the erosion of the strata at Rochester may be 2000 feet, in which case 1000 feet more must be added to the figures for both the sinking and the rising of the land. These figures are only net, and do not take into account the unknown but probably large uplift in Tertiary time, before the Pleistocene ice cap weighted down the northeastern part of the continent. On the basis of only 1000 feet of erosion at Rochester the excavation over the basin of Ontario is more than 2000 feet. This is, however, moderate as compared with other examples of deep erosion, like the valley of the Colorado river.

The development of the great dimensions of the Ontario as a subsequent valley was due to the outcropping along the east and west belt of the very thick and nonresistant shales of the Silurian and Ordovician. On the meridian of Cayuga lake the thickness of the strata from the Trenton limestones up to the Portage sandstones is over 5000 feet; and of this depth 4500 feet are shales, with only some 350 feet of limestone and 250 feet of sandstone. With uplift of the area it was inevitable that this belt of weak rocks would invite the production of a great transverse subsequent valley.

While it is certain that the Ontario valley was occupied by a great, dominant master stream, which we may call the Ontarian river, it is not positively known if it reached the sea by way of the St Lawrence valley or by westward flow to the Mississippi embayment. For various reasons which may not be recited here it is believed that the flow was westward, and it is so represented on the map (plate 5). We may now picture the evolution of the Ontarian river. In the same manner that the Mohawk river was evolved, by linking of east-and-west tributaries of the south-flowing primitive or consequent rivers, until the latter were captured and diverted, so was the Ontarian river evolved. Favoring the westward diversion of the streams, it may be noted that the rocks had less resistance on the west, becoming less quartzose and with finer grain, that with the uplifts of both Permian and Tertiary time there appears to have been produced a westward decline of the land surface toward the Mississippian lowland. These probable conditions gave the west-flowing tributaries an advantage over the eastward streams, and both sets had advantage over their trunk streams with southward flow because they were flowing along the outcrop or strike of the weak strata. By normal stream adjustment the more active west-flowing streams captured the Canadian rivers and turned them all into the westward flow of the master stream.

We can only surmise when the Ontarian river was established and the valley outlined. It might be suggested that the Permian uplift, diminishing northward raised the southern belt of New York more than it did the Ontario area and that this tended to check the south-flowing primitive streams and gave advantage to the westward flow. This would imply that the Ontario valley was initiated in Mesozoic time. Probably few geologists will admit so early a beginning for the Ontario valley. The problem involves the northward reach of the Mesozoic peneplane. Whatever the geologic date for the birth of the Ontarian river we may be sure that after it was established no subsequent continental movements diverted its flow or interrupted the valley erosion until glacial time.

We now turn to more definite history, the reversal of drainage in the western part of New York. The east and west Ontario valley had, of necessity, a south bank or north-sloping wall, and north-flowing streams were developed. The remainder of the Preglacial history relates to this northward drainage.

As the Ontario valley widened, this northward, reversed or obsequent drainage extended its control southward. By headward cutting it ate more and more deeply into the plateau of southern New York. In the erosion of a region of inclined beds, like the area involved, the divides shift in the direction of the dip, or down slope. The north-flowing streams, cutting across the outcrops, had advantage over the original south-flowing streams lying on the gently inclined beds. With continued deepening of the Ontario valley its southern tributaries gnawed back into the highland of New York until the Ontario drainage had extended its mastery over nearly all of New York west of the Mohawk and the Delaware, and over much of northern Pennsylvania. The chief exception is that of the Allegany, which flowed northward into the Erigan river (7). The Erie valley probably has a physiographic history similar to that of the Ontario. It must have been a magnificent stream which in preglacial time rolled through the Ontario valley, tributary to the Mississippi.

The Finger lakes lie in valleys which, with possibly two exceptions, belong to the north-flowing reversed drainage. A number of the obsequent valleys do not hold lakes. From the Tonawanda valley on the west to the Onondaga valley on the east we count fifteen parallel valleys, with several other valleys farther east, around to Oneida lake, which are also part of the Ontarian obsequent drainage. Probably this is the most remarkable series of parallel valleys in the world.

Plate 5 shows the reversed drainage of late Tertiary time, but the description of the map is deferred to a later chapter.

It is possible that some of the valleys of the Finger lakes district are in the lines of the primitive south-flowing streams; or, in other words, that some of these north-sloping valleys are the intrenched inheritances of the original consequent valleys, with the direction of flow reversed. The depth of erosion in the region is so great, however, that no statement can be made with confidence.

The present divides at the heads of these valleys (plates 1, 2 and 3) are clearly due to glacial filling, the preglacial divides being far south (plate 5). The Genesee valley, heading in Pennsylvania and flowing north entirely across New York, is the best surviving example of the late Tertiary drainage. Even the damming and diverting effect of the ice sheet, so successful with other valleys (plate 6), could not reverse the flow of this river; although in three localities it was so obstructed that it found new rock channels, producing the picturesque canyons at Portage, Mount Morris and Rochester (32, 40, 41).

Like the Ontario valley the trenches of the Finger lakes are surprisingly deep. Cayuga lake has a depth of 435 feet, or 54 feet below sea level. Seneca lake is 618 feet deep, or 175 feet below tide. These figures probably do not give the actual depths of the preglacial rock valleys, as there may be considerable depth of glacial filling. It is reported that at Watkins, the head of Seneca lake, a drill has pierced to the depth of 1200 feet without finding rock; which carries the rock bottom down to over 757 feet below sea level, or lower than the measured depth of Lake Ontario. Doubtless there is considerable filling in Ontario.

The former suggestion that the excessive depths of Seneca and Cayuga lakes was produced by glacial erosion was partly based on the absence of northward extension of their valleys toward Ontario, although Sodus bay, and bays eastward, do give suggestion of buried valleys. North of the lakes from Seneca eastward the preglacial river channels are buried under morainal drift and capped by drumlins.[1] Only systematic probing by the drill can map the drift-buried topography and reveal the courses and depths of the rivers which were the predecessors of the Finger lakes, and prove if they were graded to the Ontarian river.[2] This might show the existence of cataracts or cascades where the streams crossed the heavy limestones, Onondaga-Helderberg and Niagara, and the sandstone beds of the Medina.

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[1] Drumlins of Central and Western New York, New York State Museum Bulletin 111, 1907.

[2] Such exploration of the concealed geography would be appropriate educational work for the State.

West of Sodus bay only one visible preglacial valley leads northward to the Ontario. This is the capacious Irondequoit valley, close east of Rochester. It appears probable that the weaker streams of the northward drainage were thrown into east and west courses along the belt of outcrop of the very weak Salina shale, similar to the present drainage. In plate 5 the northward drainage is hypothetically gathered into four great rivers, the Genesee-Irondequoit, the Susquehanna-Seneca, and rivers of less certain location for the eastern territory.

Northward Diversion of the Susquehanna River

The most notable and radical element in the Tertiary drainage, shown in plate 5, is the northward course of the Susquehanna. That the great Ontarian river grasped the drainage of central New York, the district of the Finger lakes, appears natural; and that it seized the Genesee is a fact of present time. But that it was so greedy and powerful as to reach far south and subdue the Susquehanna is surprising. As a fact, this is not yet absolutely proven, in the lack of sufficient drill data in the stretch from Waverly through Elmira to Horseheads. But all the data acquired thus far from well borings and all the physiographic features strongly indicate such northward flow. If we could clear out the drift filling of the valleys from Owego around to Horseheads it appears quite certain that the Susquehanna would today take the north course through the Seneca valley. Adding to this probability it should be recognized that the rather narrow and youthful channel of the river from Towanda south to Pittston has been deepened to some considerable, but indeterminate, amount by the glacial flood, since Tertiary time.

The significant physiographic features of the Waverly-Elmira district are fairly shown in the maps (plates 3, 10 and 11). The Elmira quadrangle is well known to geographers as a classic example of drainage diverted by glacial interference. Unfortunately the territory in Pennsylvania, the Sayre and Towanda quadrangles, is not surveyed. Here is a wide, triangular area between the Susquehanna and Chemung rivers with the conspicuous, isolated Spanish hill rising out of the flat plain. The full understanding of the geography requires knowledge of the glacial history, which is treated in a later chapter.

The valley of the Chemung river between Elmira and Waverly is evidently a drift-filled preglacial valley. It is fully as capacious as the Susquehanna valley above Waverly, and is not the product of glacial nor present drainage. The Chemung river now lies in this stretch because of glacial diversion and is not responsible for the old valley. The preglacial path of that river lies buried in the wide valley at Big Flats and swinging north at Horseheads, while its new channel, for which it is only partly responsible, is the narrow valley southwest of Elmira.

The dimensions and form of the wide valley at Elmira and Horseheads, with the uniform curve of the steep east wall and the truncation of the spurs near Horseheads, indicate the work of a heavy stream. After reading in a later chapter of the glacial waters the reader might question if these features were produced by the southward glacial flow from central New York. Effective erosion by the glacial waters was limited, however, to a brief episode of weak flow. During the advance of the ice sheet the southflowing stream drained a lake, probably corresponding to the Lake Newberry of the ice retreat, but with outlet farther south, and it was not provided with abrasive tools. During the recession of the ice front the valley was occupied by the Elmira lake, and was receiving its filling of drift. It was only when the ice front during its advance was passing over the locality that the waters had cutting power, and then the volume was small.

The great depth of the Seneca valley is important, not only with reference to its relation to the Susquehanna river but as bearing on the great depth and peculiar form of the other Finger lakes valleys, especially Cayuga. The suggestion is that of abrupt rejuvenation, in very weak rocks, shortly preceding glaciation.

The singular character of the Susquehanna valley below Towanda has an important bearing on the history. In plate 5 the divide between the north and south drainage is drawn at Towanda. From that point south to Pittston the valley has a character unlike any other stretch in the whole length of the river. Swinging in wide meanders, apportioned to a large river, it is lying against high cliffs on nearly every outer or tangential curve. The cuttings for the Lehigh Valley railroad have only emphasized the cliffs on the east side of the river. Above Towanda the river is above its old bed, flowing in drift filling, and rarely cutting the valley sides. The gradient of the Towanda-Pittston stretch is less than that elsewhere, except the Binghamton district. Plate 5 gives basis for the doubt that this part of the present Susquehanna valley carried the flow of the earliest southward drainage. We do not know when this stretch was developed so as to acquire the river. It is certain that it carried the tremendous glacial flood, during both the oncoming and the waning of the glacier (plates 6, 7 and 8), and the present flow since glacial time.

It appears most probable that no flow of the upper Susquehanna and its tributaries ever passed south past Towanda until forced there by the oncoming ice sheet. This implies that the westward diversion of the Chenango and Susquehanna was directly into the northward flow through the Seneca valley, the Senecan-Ontarian river.

This problem would require no discussion if we knew the slope of the bottom of the old valleys, beneath the drift filling. The well records now available are not conclusive, although suggestive. The figures depend too much on the memory of the drillers, and the borings are commonly not in the middle of the valleys or along the supposed axis of the ancient valleys. The following figures are for the elevation of the rock above sea level, calculated from the depth of the well and the elevation of the ground surface. Only the more reliable and significant data are given, and the figures are not precise.

	Elevation in feet above rock
Binghamton, lowest record of rock surface	686
Owego, three wells near the south side of the valley	600
Union, rock at	580
Waverly, no records for the middle of the valley	
Chemung, no wells	
Wellsburg, no wells	
Southport, in valley of Seely creek	775
Elmira, two wells close to the east wall of valley	734
North Elmira, no rock at	749
Horseheads	550
Millport, no rock at	524
Watkins, no rock reported at 750 feet below tide	
Sayre, one well	565
Athens, one well	610
Milan, one well	692
Ulster, one well	600

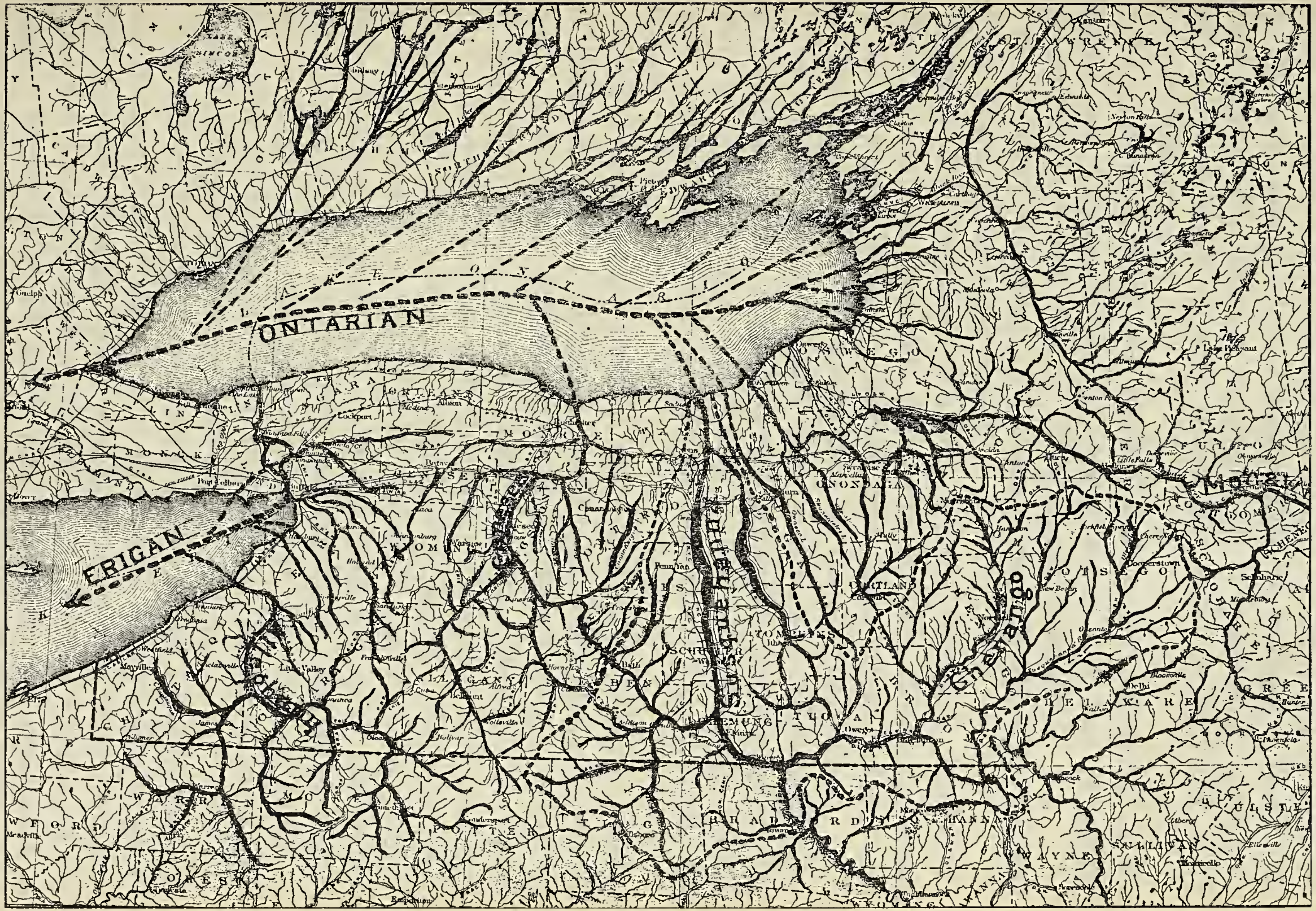
Review of the Tertiary Drainage

Plate 5

Several elements in this map, not directly related to the Susquehanna river deserve notice.

The wonderful character of the Tertiary drainage can not be appreciated without comparison with the other maps, especially plates 4 and 6. Accuracy in detail of the stream lines is not claimed,

Plate 5



Probable Drainage of Late Tertiary Time

A broken line bounds the drainage area of the ancient Susquehanna. Other broken lines mark hypothetic courses of Tertiary rivers

but the main elements are quite certainly true. The remarkable changes from the primitive drainage are better justified when we realize the enormous interval of geologic time. It might be interesting if some of the intermediate stages of the drainage between the Paleozoic and the late Tertiary could be mapped. While this might be plausibly done for some districts it would be so hypothetic and involve so much of pure assumption as not to be worth while for the whole area.

The southward reach into Pennsylvania of the tributaries of the Erigan and Ontarian rivers is clearly shown. A line of waterparting is drawn only for the Susquehanna boundary.

The Tertiary Alleghany (7), reached the Erie valley by the way of the lower Cattaraugus valley.

Between the Alleghany and the Genesee control a number of smaller streams had separate northward courses, represented today by the Cayuga, Cazenovia, Buffalo and other creeks, which with the Tonawanda were the headwaters of the Erigan river.

Two of the parallel Finger lakes valleys are represented with southward flow, the original stream direction, Canandaigua being tributary to the Genesee and Keuka to the Susquehanna. All the other central New York valleys have northward or reversed direction.

A broad valley which today is filled with drift, forming a divide at Wayland, west of Dansville, carried the Canandaigua-Dansville river. This master stream drew on southern territory, including the upper part of the present Canisteo valley, and south of Mount Morris it joined forces with the upper Genesee. This enlarged Genesee river was a rival of Susquehanna-Seneca. North of Avon the latter's course is obscured by the drift, but the only possible course appears to have been eastward along the weak Salina belt and then northward by the deep and capacious Irondequoit valley, east of Rochester. The present course of the Genesee north of Avon with its handsome canyon at Rochester, is clearly postglacial, as are the gorges at Portage and Mount Morris.

The belt of thick and very weak Salina shale, forming the surface outcrop from Niagara river to Oneida lake, passing south of Rochester and through Lyons and Syracuse, forms today a shallow depression having Onondaga limestone as its south border and the Niagara limestone as its north rim. Evidently this depression is an inheritance of the Tertiary topography, which has been only partially filled by drift, for with only two notable exceptions all the streams which enter the depression follow it either east or west. The Niagara and Genesee rivers cross the sag by postglacial channels. Practically all the drainage which enters this belt becomes tributary to either the Niagara, Genesee or Oswego rivers, all three being in postglacial rock canyons.

This Salina outcrop depression was a controlling feature in Tertiary time, for only a few old valleys trench the Niagara-Medina scarp to enter the Ontario valley. The only ones in New York are Irondequoit, the buried valley which probably is represented by Sodus bay, and perhaps valleys correlating with Port and Fairhaven bays. The three latter are obscured by glacial drift and superposed drumlins, but are the only reasonable outlets for the waters of central New York.

The present Cohocton valley (plate 24) is represented as bisected by a divide above Bath, which threw the Keuka outflow into the Susquehanna.

The Cayuga valley, comparable in dimensions with the Seneca valley, presents a difficulty in the mapping. It claims some territory on the south but has no heavy tributaries. The broad northeast-by-southwest "hung-up" valley, having Cortland at the middle (plates 2 and 4), has no low outlet at Ithaca, and no sufficient escape southward. The Tertiary flow apparently dissected this ancient valley, and the upper part is here carried northward past Tully to the Onondaga valley. It is a choice between this and the Owasco valley. The Cayuga flow is added to the Susquehanna-Seneca river.

The break between flow to the Mohawk and to the Ontarian is made at Little Falls (25), and the Rome-Oneida lake trunk river is sent west to Cross lake and then northwest through Fairhaven bay. This is the most uncertain district to map. Possibly all the eastern waters joined the Susquehanna-Seneca river. The reader may properly try to make some other disposition, for the region is all covered by the excellent topographic sheets. Certainly we must await the revelations of the drill.

The drainage of the western Adirondack area is gathered into the Black river which is sent northeast down the St Lawrence valley. The latter valley has been so scoured by the ice abrasion that the old stream features are gone. For the territory east and north of Lake Ontario Wilson's mapping in paper 18 is practically followed.

The glacial interference which is responsible for the remarkable change from Tertiary drainage to the present hydrography is described in the next chapters.

PLEISTOCENE HISTORY OF THE SUSQUEHANNA RIVER

Introductory Statement

Geologists who are conversant with the area of the Great lakes and the Mississippi valley are confident that more than one ice sheet of Pleistocene time invaded that territory. This has suggested or encouraged the belief in multiple glaciation over New York and New England. The writer is inclined to doubt the validity of this view and to believe that all the glacial phenomena of New York, New England, eastern Pennsylvania and New Jersey have been produced by a single ice invasion, that of the Quebec (Labrador) glacier, of the closing epoch of the glacial period. Considerable oscillations of the ice front are probably responsible for features which have been interpreted as records of distinct ice sheets.

The problem of unit or of multiple glaciation over New York need not be solved, however, for our present study, because the effects upon the drainage of any repetition of glaciation would probably be cumulative. Glaciation did not change the large topography of Tertiary time nor the controlling lines of ultimate outflow, which in New York are the Mohawk valley and the Susquehanna escape. It is a fair assumption that any succession of ice sheets would probably have similar directions of flow, and similar alignment of their borders; and quite surely so if they had their centers or feeding-grounds in the same region. For the Quebec glacier, the only ice for which we have any clear evidence in New York, this center of accumulation is apparently between James bay and the St Lawrence valley. For the purpose of this writing we assume only one episode of glaciation.

The first effect of the invading ice sheet was to block any northward drainage and to force such waters into other and higher outlets. During the waning of the ice body and the recession of its margin the damming effect on the rivers was similar, but in reverse order. The south-leading streams were greatly augmented in volume, and their channels greatly deepened and enlarged. The dominant south-leading valleys of the present drainage which are discordant with both the primitive drainage (plate 4) and with the Tertiary flow (plate 5) owe their prominence to the forced glacial drainage. These lines are shown in plate 6.

Two other principal effects of the glacier were the local filling of some old valleys, thus diverting the stream flow, and the shifting of divides. In north and south valleys the divides were necessarily moved northward, or toward the ice. The most remarkable change of this sort is seen in plates 5 and 1, where the south limit of the Ontario basin is shifted from northern Pennsylvania to the present head of the Finger lakes. This was accomplished by heavy morainal filling and not by headward erosion of the flooded streams.

On the Susquehanna system the main effects of the glacial interference were the turning of the river southward at Waverly, and the addition of territory by the Canisteo, the Cohocton and the Tioughnioga creeks. The head waters and upper tributaries, or the river above Waverly, were not seriously changed by the glacial occupation.

The Pleistocene history of the Susquehanna river involves both New York and Pennsylvania; and the features are as interesting and important in Pennsylvania as in New York. Indeed, the lakes and the high-level deposits in New York were partly dependent on the barriers of drift in Pennsylvania, and the story can not be told for New York without some account of the events down the river. In interstate comity, however, it is desirable that as far as practicable each state should publish the story of its own province. The reader who desires the glacial history of the entire river will obtain paper 43 of the list of writings.

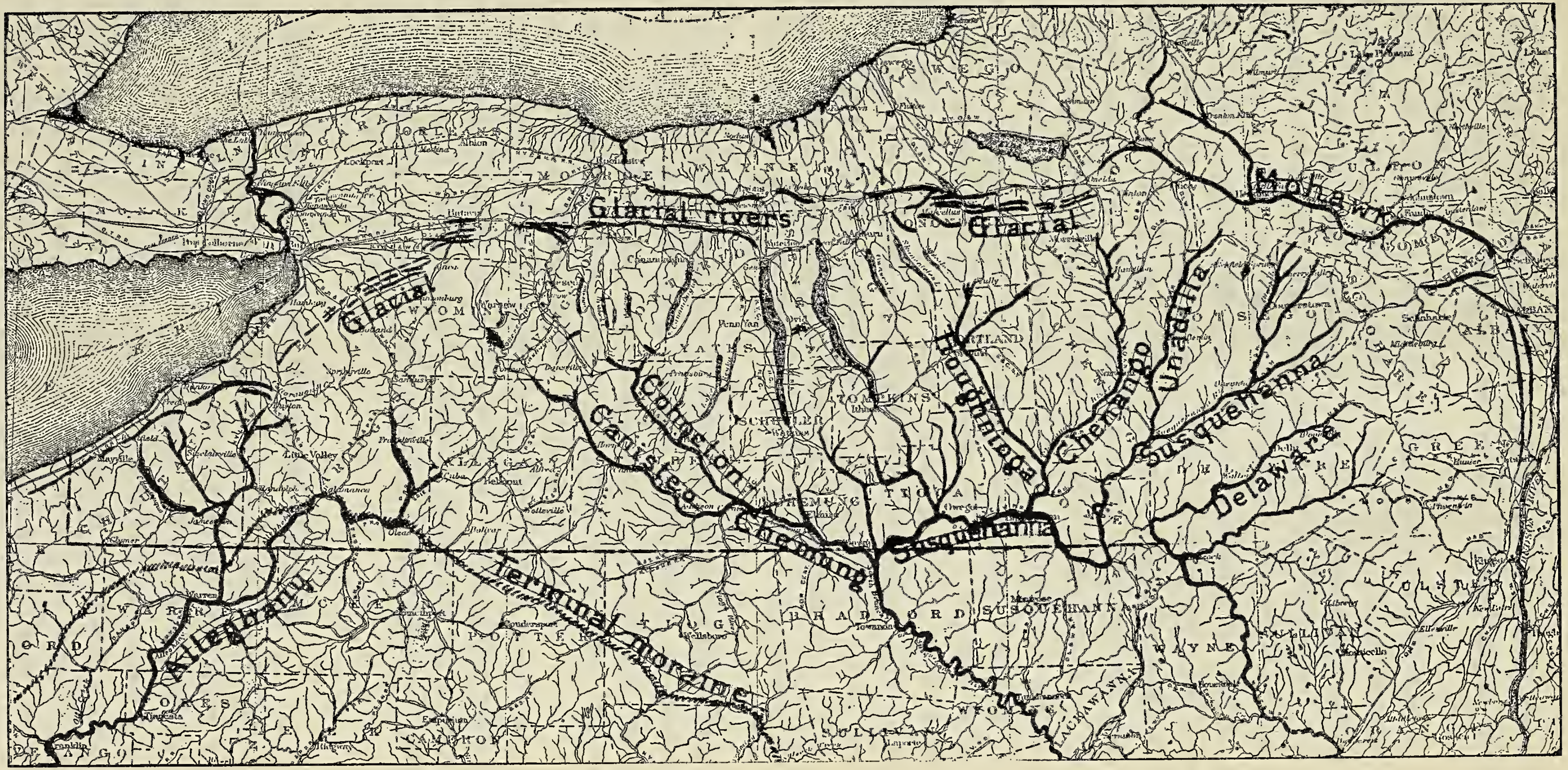
The Ice Invasion; Forced Glacial Drainage

The effects produced by the oncoming ice sheet are a matter of inference. We are sure that the blocking of the drainage must have been in succession, or in order of time the reverse of the same effect during the melting of the ice body and the northward sweep of its southern margin. The changes in the drainage during the waning of the glacier are subjects of observation, and have been depicted in papers 33 (plates 34–42); 34 (plates 2–17); 42 (plates 1–8). The best that could now be done would be to reproduce the serial maps in reverse order. Two of them are reproduced here as plates 7 and 8.

The principal lines of glacial drainage are shown in plate 6. It may be seen that some of these streams do not appear in plate 5, because they were not existing, at least in their present form, in Tertiary time.

Besides forcing all waters into southward flow the ice sheet rubbed its rock-rubbish into the valleys, especially those which were transverse to the glacier movement, and dumped its marginal

Plate 6



Main Lines of Glacial Drainage

or moraine drift in such volume in many places as to entirely divert the streams. The moraine fillings at the heads of the Finger lakes valleys are good examples.

Beginning at the western end of the State we find that the ice-impounded waters which were forced across the divide between Mayville and Gowanda were gathered into the Conewango, which, with the morainal blocking, has dismembered the Tertiary Alleghany river. The area of the upper Cattaraugus was drained south by the Ischua creek, which with Oil creek is mapped as forming the Olean creek. The Canisteo and Cohocton rivers are new streams, uniting with the Tioga river from the south to make the large Chemung river. The short, but important, Horseheads river, the outlet of the glacial Lake Newberry (28) is indicated. The Cayuta creek, joining the Susquehanna river at Waverly, is another new stream. The Spencer and the Willseyville creeks, forming the Catatonk creek, carried the glacial overflow of the Cayuga valley. The Tioughnioga river is another new channel, which carried the forced waters of the Skaneateles-Cazenovia district. The Chenango river and the upper branches of the Susquehanna river, having southward courses, naturally carried the glacial flow.

The Genesee valley will be noted in the chapter describing the ice retreat.

The lowest southward escape for the glacial waters of the Finger lakes region was by the reversed Seneca-Susquehanna at Horseheads-Elmira. This flow was the longest in life and largest in volume of any southward flow, but was surpassed by the Iromohawk, leading east from Rome to the Hudson estuary.

The advancing glacier greatly augmented the flow of the Susquehanna, especially in Pennsylvania, not only by forcing the waters of other river systems into tributary connection but by the copious addition of the water produced by the melting of the glacier itself, both in advance and removal.

Extent of the Glacier; Terminal Moraine

By its growth in storing the snowfall of the northland the Quebec glacier eventually reached New York and buried all the State, except a small area at Olean and Salamanca. The slow, unsteady but irresistible invasion by the ice sheet covered an unknown space of time, estimated as at least scores of thousands of years; perhaps 100,000 years. The thickness or depth of the ice increased from a few hundred feet at the margin to many thousand feet in the north part of the State. The plucking, grinding and transporting power of the glacier were proportionate to its weight and pressure and somewhat inversely as its rate of motion. This geologic work of the glacier is principally shown in the masses of rock-rubbish (glacial "drift" or "moraine") dropped along the lines where the oscillating margin lingered in its retreat.

The maximum reach of the glacier across New Jersey, Pennsylvania and New York has been depicted in many publications, and is shown in plate 8, New York State Museum Bulletin 160 (34). The border of the ice sheet is represented in all those maps as a quite continuous or direct line, paying slight attention to the deep valleys or the mountain ridges across which the ice front rested. This is certainly an error, due to following the original maps of the "terminal moraine" of Lewis and Wright.[1] Those early explorers did not sufficiently recognize the lobations of the ice front which occupied the valleys. The glacier was a plastic body which conformed to the topography of the ground surface. Recent study has shown that the ice lobes pushed far forward in the valleys and left masses of drift miles in advance of the supposed "terminal moraine." In the country of high relief the ice margin was a very indefinite and ragged belt. The writer now agrees, from some study on the ground, with the contention of E. H. Williams, to the effect that the supposed pre-Wisconsin drift in the region of Bethlehem, Pa., is only the most advanced deposit of one ice sheet. The entire belt of the terminal drift requires careful revision. In plate 6 the Lewis and Wright line of terminal moraine is partially shown.

The Ice Removal; Recurrence of Glacial Drainage

Now we are not depending on theory but on facts of observation.

At its greatest reach the continental glacier reduced New York to the condition of Greenland at the present time. How long the State remained in that condition of cold storage is not known, but probably scores of thousands of years. Eventually the climatic processes which had very slightly lowered the world temperature so as to change the precipitation over Quebec from rain to snow were checked, and finally reversed. The ice body slowly melted, chiefly at its margin. It had expanded when the snowfall exceeded the melting. It diminished when the spreading motion could not equal or compensate for the melting.

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[1] Report Z, Second Geological Survey of Pennsylvania.

During the farthest reach of the ice sheet the north branch of the Susquehanna was reduced to a small stream of the glacial outflow, heading below Berwick, Pa., and having a length to Northumberland of about 30 miles. Not until the ice front had backed away to north of Waverly did New York have any renewed Susquehanna. As the ice front gave place, by northward recession, the river and its tributaries extended their headward growth, as glacier drainage.

The land drainage was, of course, restored as the ice sheet removed, but with such changes as the drift barriers compelled. The forced drainage of the ice invasion was now repeated in reverse order for the main outlets, but with modifications in minor channels due to the morainal damming. The most conspicuous examples of the latter are seen at the divides south of the Finger lakes (30, plate 3). An excellent example of river diversion and cutting of new channels is seen in the Chemung channel southwest of Elmira (plate 10).

The story of the glacial drainage in New York has been related in former papers (29, 33, 34, 42). The Genesee valley is the best illustration in any single valley of the changes produced by the ice blockade. The history of the valley waters during the ice removal has been imperfectly told (28, 32, 33). Its drainage history is probably the most complex of any valley in the world. During both the advance and waning of the glacier its waters were forced into all the principal lines of outflow for New York waters.

In plate 6 the east and west lines of drainage show the latest ice control in New York, these being subsequent to the full restoration of the Susquehanna system.

Changes in Volume of the Susquehanna River

One of the most interesting and important elements in the history of the Susquehanna river is the extreme variation in its volume of flow, due to glacial interference, and the effect of that on its work of transportation and deposition of detritus.

When the ice margin lay at or south of Waverly the volume of the river was zero for land drainage in New York, but was some unknown amount from the subglacial flow of the melting ice. During the removal of the ice sheet and the retreat of its south front the volume of the river increased, until in extreme summer flood it may have been several times larger than Niagara. Plates 7 and 8 (34, plates 12 and 13) show the magnificent glacial Susquehanna. The reader will note that the river carries all the drainage of western New York from the Batavia meridian on the west to near Albany on the east, and in addition all the land and glacier drainage from the Adirondack area. The river systems that were tributary were most of the Genesee, most of the Oswego, plus the Schoharie and part of the Mohawk, and plus the upper reaches of all the streams radiating from the Adirondack mountains. To this must be added the water from the melting ice sheet, with 500 miles of margin and also the precipitation and the melting from the sector of the dome-shaped ice body which drained toward New York, estimated at about 41,000 square miles.

It is not possible to calculate the actual volume of the glacial flood in the Susquehanna valley because of uncertainty as to the meteorologic and geologic factors involved in the removal of the ice sheet, but it is possible to make some reasonable estimates which will give some conception of the order of magnitude of the enormous glacial flow.

When the glacier was invading New York it was storing all the precipitation on its central area and probably part of the snowfall on its marginal belt. When it was waning it was not only shedding all the precipitation upon its entire area but was also losing its own mass. The summer run-off from the waning ice sheet was the rainfall over its surface, plus the melting winter's snowfall, plus the water from the melting ice body.

Our problem requires several assumptions. The general atmospheric circulation and the cyclonic paths are believed to have been similar to the present time; and the chilling effect of the ice sheet probably intercepted some of the moisture which today is carried farther eastward. Hence we may assume first that the precipitation over southern Canada and New York, during the phase represented in plate 8, was not less than it is today. It may have been larger.

The second assumption has to do with the area and drainage of the glacier. The dome-shaped ice body, with its center probably in southern Quebec, must have shed its water in all radial directions. A sector of the glacier drained southward toward New York and into the grasp of the Susquehanna. The area of this sector is moderately estimated at 41,000 square miles. From about one-half of this sector the water passed through Lake Newberry and the Chemung valley (plates 7 and 8), and from the other half by streams and Lake Herkimer to the river above Owego.

The glacial drainage from the New York area, both the ice-free and ice-covered as shown in plate 8, is calculated (from the maps of the State Conservation Commission [1915]) as derived from 26,433 square miles. Of this area about 19,581 square miles drained into the upper tributaries of the river, including the Chenango; while the water from 6852 square miles reached the river at Owego and Athens (below Waverly).

If to the drainage from the New York area we add the contribution from the ice sheet over Canada and Lake Ontario basin, we find in round numbers 40,000 square miles of glacial precipitation area draining to the river at Binghamton, as compared with only 3930 square miles of the present river drainage; while below Waverly the total glacial contribution from over 67,000 square miles was in the river. The present drainage area carried by the river at Wilkes-Barre is only 9810 square miles. These figures appear in the following table:

TABLE 7

Drainage areas of the Susquehanna river

GAGING POINTS	PRESENT DRAINAGE AREA, IN SQUARE MILES	GLACIAL DRAINAGE FROM NEW YORK TERRITORY, IN SQUARE MILES	GLACIAL DRAINAGE, FROM CANADA, IN SQUARE MILES	TOTAL CONTRIBUTED GLACIAL DRAINAGE, IN SQUARE MILES
Binghamton	3 930	19 581	20 500	40 081
Wilkes-Barre	9 810	26 433	41 000	67 433
Harrisburg	34 030	26 433	41 000	67 433

The third assumption is that the water from the melting glacier was at least equal to the precipitation over the area of glacial drainage. The summer rains helped the solar radiation to liquefy the ice. And the run-off was probably larger than over the Susquehanna area to-day, which is about one-half of the precipitation. On the glacier the water ran off promptly, with small evaporation, and the latter was probably reduced in the cool territory bounding the ice sheet. Moreover, the run-off was concentrated in the warm half of the year. These probable conditions permit the fourth assumption that the total annual run-off from the glacial territory was double the amount per square mile of New York today. It might have been much larger. Furthermore, the run-off was concentrated in one-half the year. This suggests as a fifth assumption the possibility of at least temporary summer glacial flow 4 times the volume per unit area of the present time.

Modifying the later assumptions of great flow we recognize an equalizing factor, some storage by the glacial lakes (plates 7 and 8), through which the glacial run-off had to pass. These lakes were so small compared to the great total areas of the glacial drainage that they may be neglected in the following calculations.

The flow of the Susquehanna river has been gaged at Binghamton, Wilkes-Barre and Harrisburg. Using the data given in the United States Geological Survey Water-Supply Papers we can calculate the river flow, under the above assumptions, using the drainage areas of the preceding table.

Adding to the flow from the drainage areas of the present river the contribution from the glacial areas we find that even on the low basis of the annual mean flow we must for Binghamton multiply the river flow by 11, for Wilkes-Barre by 7.87 and for Harrisburg by 3.8. It is with the flood conditions, however, that we are chiefly concerned, and if we figure according to the fourth assumption that the summer flood of the glacial area was per unit area twice the mean flow of the present river, we have to multiply the present flow at Binghamton by 21, at Wilkes-Barre by 14.74, and at Harrisburg by 6.6. If we use the fifth assumption that the summer flood from the glacial area was per unit area 4 times the present mean flow of the river, we have to use as multipliers, at Binghamton 41, at Wilkes-Barre 28, and at Harrisburg 12. The results are given in the following table.

TABLE 8

Glacial river flow with estimates based on the present mean annual flow

GAGING POINTS	PRESENT MEAN FLOW, IN SECOND-FEET	GLACIAL FLOW BY PROPORTIONATE AREAS		
		Glacial run-off same as present river	Glacial run-off twice the present	Glacial summer run-off 4 times present
Binghamton (record of 1902-04)	8 819	97 009	185 199	361 579
Wilkes-Barre (record of 1900-11)	14 661	115 382	216 103	410 508
Harrisburg (record of 1891-1911)	37 225	141 455	245 685	446 700

The above table makes the glacial flow at Harrisburg, even with the run-off per unit area counted as only twice that of the present mean flow, almost equal to the greatest recorded flow of Niagara (see next table). The figures for a summer flood of 4 times the volume of the present mean river flow are probably nearer the truth, and not excessive for at least occasional limited periods.

Perhaps a better basis of calculation is to take as the unit of flood flow the average of the maximum daily flow of the river for the same series of years, and making the moderate assumption of equal summer flood and run-off from the glacial territory. The multiples for the drainage areas are given in parenthesis. The figures for the Niagara and St Lawrence rivers are given for comparison.

TABLE 9

Glacial river flow with estimates based on the annual maximum daily flow of the present river

GAGING POINTS	ABSOLUTELY RECORDED MAXIMUM DAILY FLOW, IN SECOND-FEET	Average of maximum flow	GLACIAL FLOODS BY PROPORTIONATE AREAS	
			Adding only New York glacial area	Adding total glacial area
Binghamton	96 250	83 110	498 660 (X 6)	914 210 (X 11)
Wilkes-Barre	217 700	123 808	458 089 (X 3, 7)	974 368 (X 7, 87)
Harrisburg	543 500	277 000	581 700 (X 2, 1)	1 052 600 (X 3, 8)
Niagara river	257 800			
St Lawrence river	268 000			

In the above table Binghamton has a larger glacial flow than Wilkes-Barre, which of course is impossible. The discrepancy is due to the meager data for Binghamton, covering only 3 years, and those evidently of very heavy floods. The fairer calculation for Binghamton will be to use the percentage relation of the average to the absolute in maximum flow of the other two stations, covering 12 and 22 years, which is 54 per cent. This gives Binghamton an average maximum flow of 51,975 second-feet; and glacial flow of 311,850 and 571,735.

It must be understood that the figures in the above tables are intended only to give some idea of the order of magnitude of the glacial flood.

Fortunately we are able to check the above rather crude estimates of flow based on areas by direct calculations on the stream dimensions, as suggested by the valley deposits. In New York the conditions are not favorable for hydraulic estimates. From Waverly to Great Bend the waters were practically lake waters, while two moraine dams between Great Bend and Lanesboro produced slack water in the irregular valley up toward Cooperstown. The dimensions of the prism of stream flow have not been determined anywhere in New York, but in Pennsylvania we find more favorable opportunity.

Below Wilkes-Barre is the flumelike channel extending from West Nanticoke for 12 miles, the Shickshinny canyon—with quite uniform dimensions and slope. The maps and diagrams in the Pennsylvania paper on the Susquehanna (43) show the valley characters and the features of the glacial flood.

Using the Shickshinny topographic sheet, seven cross-sections of the glacial river were measured, giving an average surface width of 2821 feet, a mean bottom width of 2400 feet, an average depth of 45 feet; and a gradient of 0.5 feet per mile. Charles C. Hopkins, civil engineer of Rochester, specializing in hydraulics and sanitation, has kindly made calculation from the above data. Basing his computation on a cross-sectional area of 117,472 square feet, as the average of the seven cross-sections, and using Kutter's formula with n equal to 0.03, and making C (in the general formula Q equals $A.\ C.\ \sqrt{R.\ S.}$) equal to 100,4, in which general formula

Q equals the flow in feet per second
A equals the cross-sectional area in square feet
R equals the hydraulic mean radius
S equals the sine of the slope

he computes the flow through the Shickshinny gorge as 787,000 second-feet.

Comparing this figure with the estimates for Wilkes-Barre in tables 8 and 9 it will be seen that they are consistent and reasonable.

It is apparent that we are considering a river subject under unusual conditions to remarkable floods, with high gradient, and having very great power. The high sand plains in the river valley, even in the lower part where no damming appears possible, require flood sufficient to give very great depth of water.

When the ice sheet was invading New York the glacial flooding began rather suddenly, and the volume declined as the growing glacier reached southward, until the river was extinguished to below Berwick, Pa. When the ice front receded, the floods increased in volume, the work being largely transportation, with deposition in sections of diminished velocity; and the maximum flow was the latest.

Another factor is important in relation to the height of the floods. During the moderate flow of the ice removal the river was heavily loaded with coarse detritus, and deeply aggraded its channel. When the heavier floods of the closing glacial phase poured down the filled valley, they rode at levels far above the present valley bottoms; and the narrow rock passes at Harrisburg and Columbia were partial barriers and helped to lift the water levels.

It must be emphasized that the enormous volume of the glacial river was repeated, occurring when the glacier invaded New York and again when it passed off the State. The effects or geologic work of the two floods, however, were unlike. It is probable that at the time of the ice invasion the continent stood higher than today, which gave a steeper river gradient. This increased the river's power of erosion, especially in the first great flood when armed with the detritus contributed by the advancing glacier. The drilling effect on the rock bed of the river may account for the peculiar "deeps" in the channel below Columbia, described by E. B. Mathews,[1] and the large depressions in the old channel in the Wilkes-Barre district, described by William Griffith.[2] For further discussion see paper 43.

The great weight of the Quebec ice body evidently depressed the glaciated area, and when the ice sheet melted away the land was much lower than it is today, as described in the next chapter. The effect of the diminished gradient, added to that of the drift barriers in the valley, produced drift-barrier lakes and sluggish flow the entire length of the river from below Wilkes-Barre to the headwaters; and also in the tributaries. In consequence the river in many stretches was depositing sand or gravel, or aggrading its valley.

Changes in Land Elevation

That the glaciated area of northeast America was below its present level when the ice sheet melted away is a fact of observation. The evidence is found in uplifted marine fossiliferous deposits and sea beaches, in the high deltas of rivers flowing to the sea, and in the raised and tilted shore lines of the glacial lakes. The amount of the depression and the oceanic submergence was greater than has usually been estimated, and much more than is commonly suggested by the stronger and more easily recognized phenomena. This subject is treated in former writings (36–39, 42) and the included maps (figures 1 and 2) are the results of long and wide observation.

It is probable that the postglacial uplift, which is measured by the depth of land submergence in the sea when the glacier was disappearing, does not represent the full amount of the downthrow, and that at the beginning of the Pleistocene time the area stood

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[1] Submerged Deeps in the Susquehanna River. Bulletin Geological Society of America, Volume 28, 1917, pages 335–46.

[2] An Investigation of the Buried Valley of Wyoming. Wyoming Historical and Geological Society, Proceedings, Volume 6, 1901, pages 27–36.

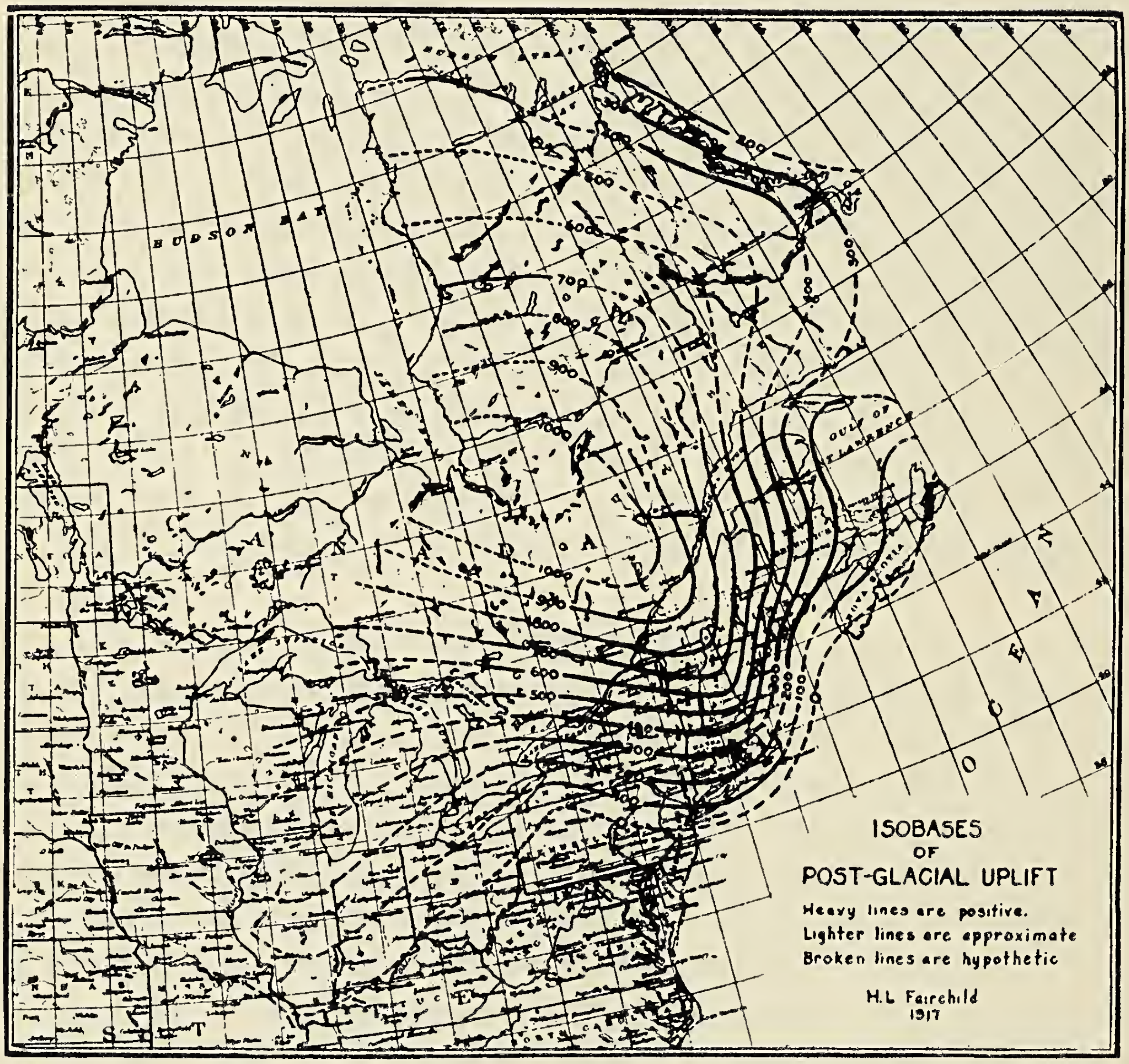

Figure 1 Postglacial Uplift of Northeastern America

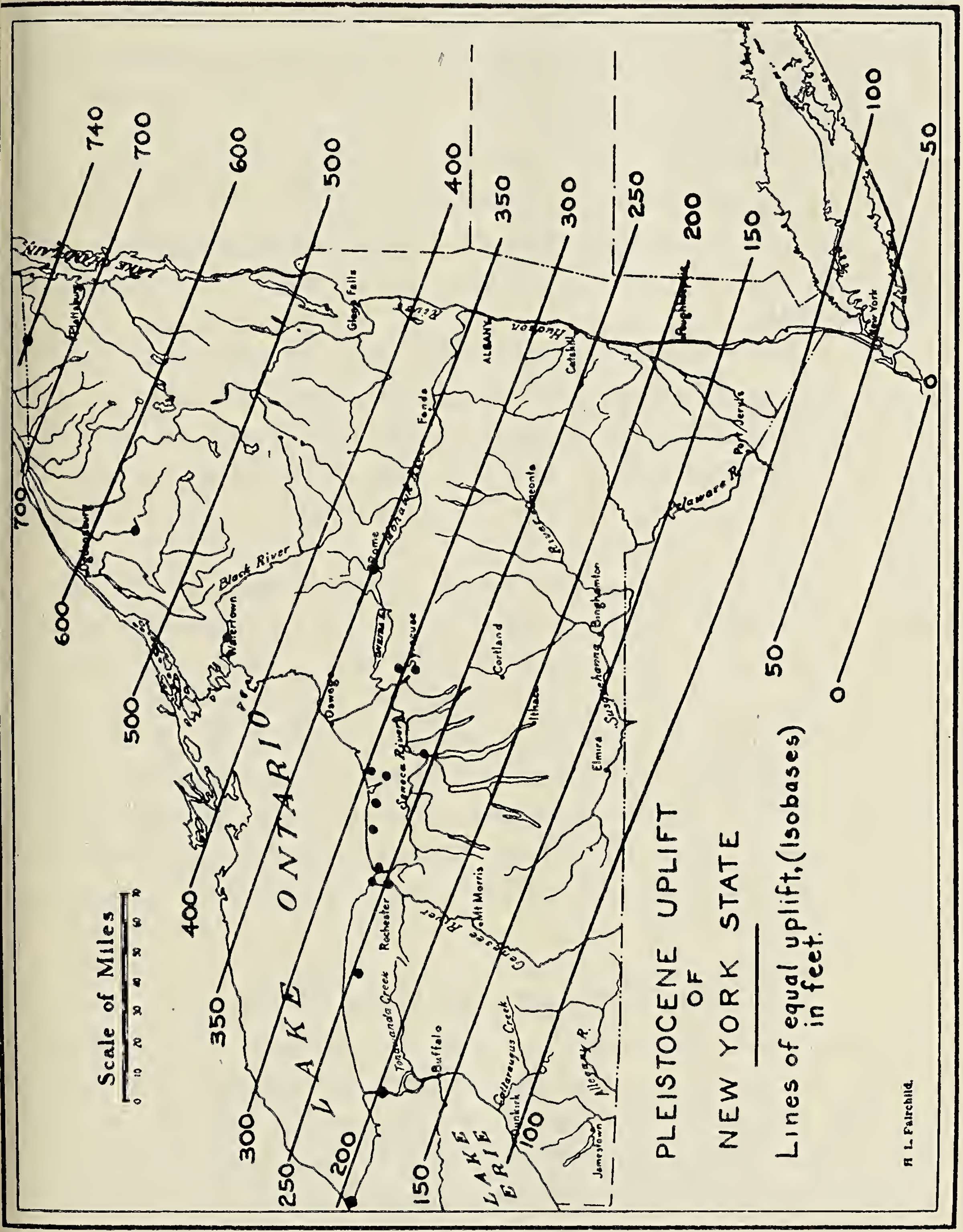

Figure 2 Isobases of the Postglacial Uplift of New York

much higher than it is today. It is supposed that the excessive weight of the ice cap, continuous for certainly scores of thousands of years, and perhaps a few hundreds of thousands, depressed the earth's rind, beneath the ice-covered territory, and that the elastic reaction or upward expansion has been only some fraction of the previous depression. The subject is a difficult problem in geophysics and awaits mathematical study.

The lower altitude of northeastern America at the time when the ice sheet melted, and the subsequent tilting uplift, are very important in this study because they help to explain the low gradient and sluggish flow of the south-leading streams with their extensive valley deposits.

In any study or use of ancient water levels in northeastern America it is necessary to take into the account the tilted uplift of the land on all sides of the upraised and dome-shaped area, and also the direction of steepest tilting. In New York the tilt or up-slant is about 2.5 feet a mile, in direction 20 degrees east of north (figure 2).

Some apparent discrepancies found in the heights of the water planes, as registered in the valley deposits, find explanation in this land deformation. For example, the deltas and shore lines in the northern part of Binghamton have elevation of 940–5 feet; but when we go up the Susquehanna valley to Great Bend we find the summit of standing water at only about 915 feet. One would expect river planes to rise up stream, or lake planes to remain level. The maps show that Great Bend lies some 10 miles south of the isobase of Binghamton, and therefore the originally level plains are properly 25 feet lower.

Drift Barriers and High-level Waters

Not only the main valley of the Susquehanna river but the branches also hold vast deposits of sand and gravel which today are merely remnants of extensive stream and lake fillings at high water levels. In New York three causes are recognized for the elevated waters: (1) the immense volume of the river in the early and closing episodes of glaciation; (2) the lower altitude of the land and the diminished gradient of the streams; and (3) the barriers of glacial and stream drift. In Pennsylvania we find a fourth cause, in the several narrow rock passes where the river breaches the mountain ridges. The first two factors have been considered and the others must be described.

The barriers left in the valleys were of two types: those truly glacial or morainic, built in contact with the ice margin, and those piled by the stream itself. The northward recession of the ice border was not only slow but spasmodic, probably by oscillations or retreats and readvances. The more massive deposits, the moraines, were built by the valley ice lobes at their readvanced positions, and in some places these were sufficiently massive to serve as temporary dams to the subsequent river flow. The evidence of such dams is scanty because the tremendous volume of the river in its latest glacial phase and with its continuous normal flow ever since, has swept out most of the dams, or made them doubtful. Two moraine dams have been found, both of them in the big bend of the river between Lanesboro and Great Bend villages.

The water flowing from the melting glacier was heavily loaded with rock stuff (rock-flour, sand, gravel, cobble, bowlders). Where this detritus was spilled into lakes, or standing water, it was piled as mounds or knolls (kames or kame-moraine). Kames are essentially morainal, being frontal or peripheral deposits at the ice margin, which in the present case are the ends of the valley lobations. A large part of the glacial valley deposits will classify as kame.

When the glacial outwash was concentrated in streams of rapid flow the detrital burden was swept down stream. These streams were usually full-loaded with detritus, and aggraded or built up their beds so as to give the necessary gradient for pushing along the coarser stuff. Remnants of the valley fillings, so-called " valley-train," appear in the south-leading valleys of high gradient as the high-level benches and terraces along the valley sides, although more or less mingled and confused with the deltas of the tributary streams. Such combined deposits are more in evidence at, or just below, the junction of the tributaries. Examples will be given below, in the areal description.

In the terminal moraine belt in Pennsylvania such volume of rock-rubbish was piled in the Susquehanna valley, by the combined work of the ice and water that the river channel was deeply filled for a long distance, and the waters of the Wilkes-Barre region were lifted to high level. This most effective and important of the drift barriers was in the canyon section of the valley, extending from West Nanticoke to below Shickshinny. This dam held a large lake in the Wyoming-Lackawanna basin, named here the Wilkes-Barre-Scranton lake. This lake and the depressed altitude of the land in northern Pennsylvania and New York, with some help from drift barriers, produced high-level and slack waters in the entire system of the Susquehanna above Pittston. The features in Pennsylvania are described in paper 43.

The most extensive body of quiet water in New York lay in the stretch of broad valley between Corning and Great Bend, Pa., now named the Elmira and Binghamton lakes. As this stretch has east and west direction, and therefore has suffered small tilting, the fact of horizontality of the water and the detrital plains is more evident.

The lake at Lanesboro, held up by the moraine dams at Susquehanna village and above Great Bend, served as the base level for the water of the upper river, and with the probable help of other barriers up the valley the waters were held much above the present river channel in all the branches, even to the Mohawk divide. The same is true of the Chenango valley, the flow being graded to the Binghamton lake.

On first thought the above facts are surprising and puzzling. The southern part of the river valley in Pennsylvania, including the moraine belt and the principal drift barrier, was deserted by the waning glacier thousands of years before the ice was removed from New York, and it might be supposed that the southern barrier would have been all swept away long before the ice front receded to New York. But there are some complicating factors. One is the long persistence of the Nanticoke-Berwick dam. Erosion of this great barrier must have begun as soon as the ice front lay on the Wilkes-Barre-Scranton lake, for the latter was a catchment basin for the drift above. The Nanticoke filling, however, was some 20 miles in length, while the valley waters were high all the way to Columbia. The drift dam could not be eroded locally or in sections but had to be lowered throughout its entire length. The detritus removed from the upper end of the dam was added down stream. It was tedious work, for the drift was largely coarse material, including multitudes of huge bowlders, and these had to be tumbled the whole length of the river into Chesapeake bay. Second, during all the time of the northward retreat of the ice front the glacial outwash continued to load the streams with coarse detritus and the energy of the river was chiefly used in transportation of the new stuff rather than in erosion of the old. For much of the time that the ice lay on the river, deposition was opposing erosion, especially in the stretches of lower velocity. The third factor is the depressed altitude of New York. The land uplift appears to have been a progressive wave movement, from south to north, following the reced-

JOHN M. CL
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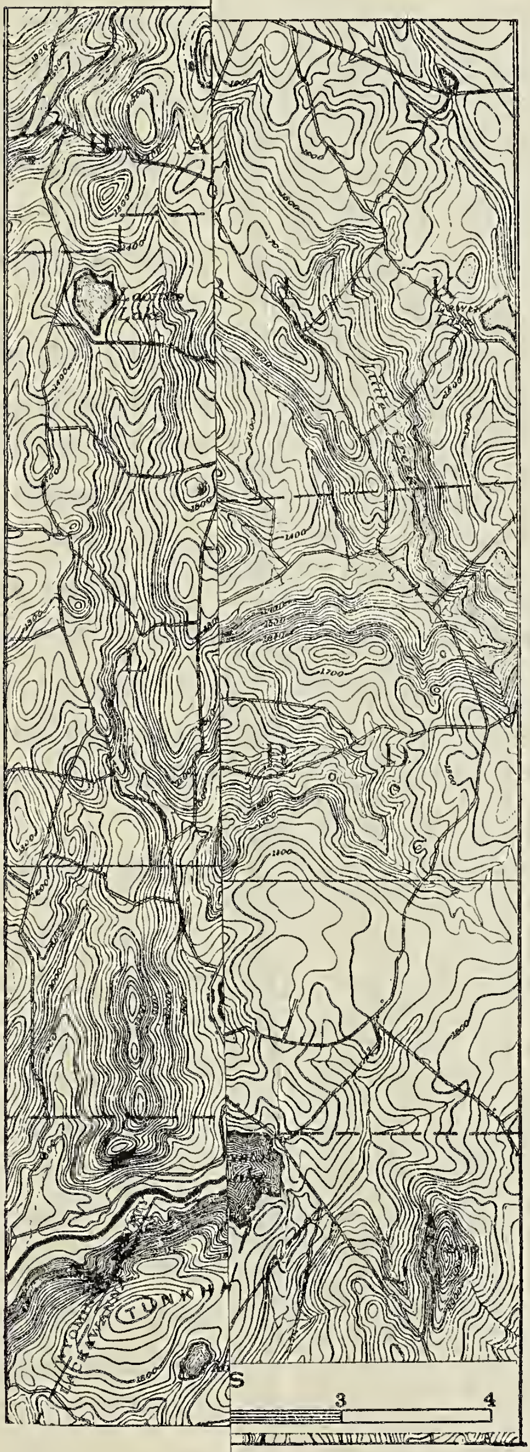
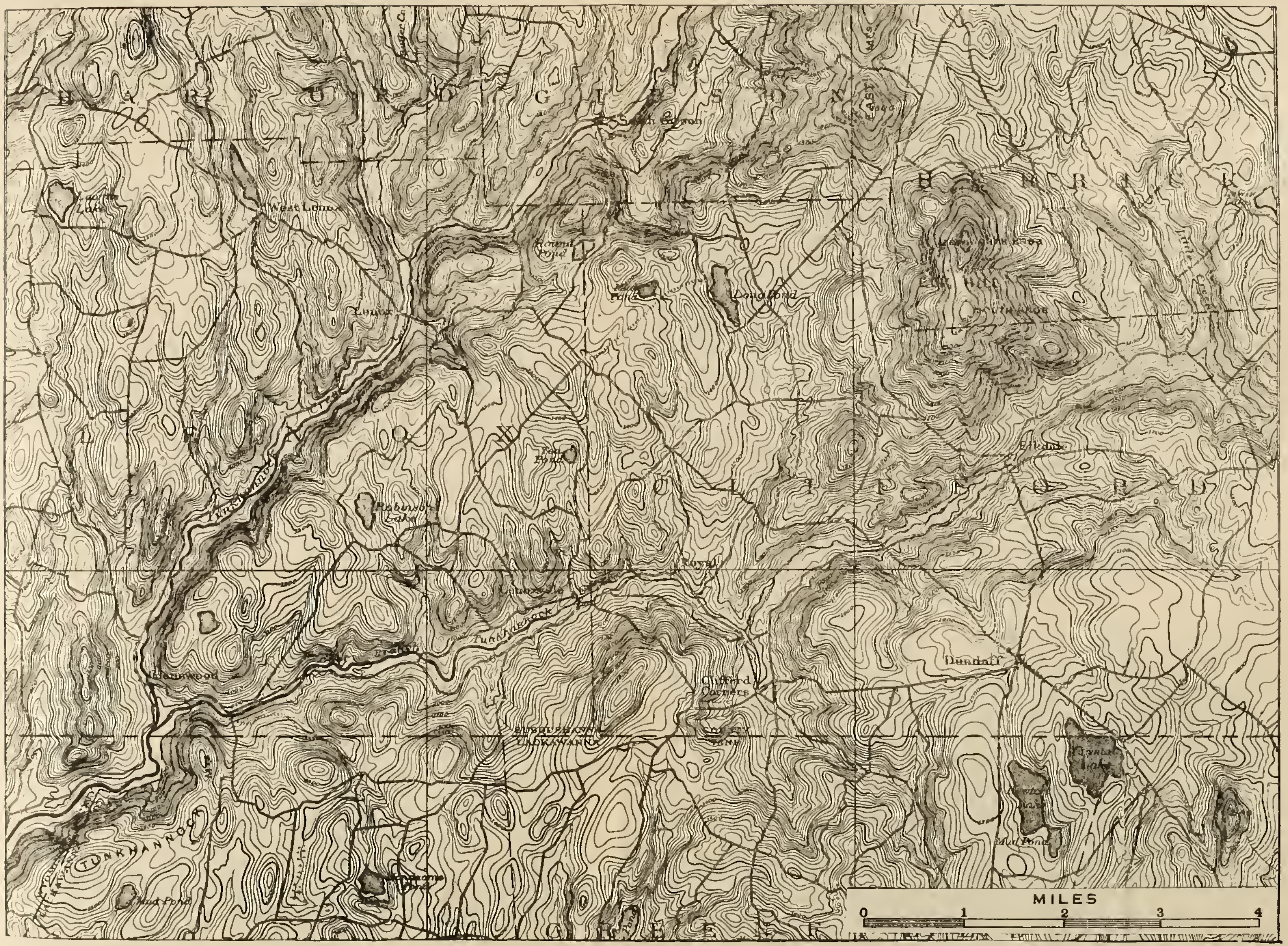
ETIN 256 PLATE 9





Elk Hills, in Northeastern Pennsylvania

ing ice margin and relief of weight. It is probable that some, or most, of the rise of land in Pennsylvania took place while New York was yet low. While the effect of this would be to quicken stream flow and increase erosion in the rising area, it would diminish the stream gradient northward, reduce velocity and encourage deposition instead of erosion. The fourth point has to do with the closing flood. The latest glacial flow was the greatest, as shown in plate 8, and until the ice front had passed across the Mohawk divide; at Springfield and East Springfield (plate 21), it was contributing detritus to the headquarters of all the tributary streams. Consequently, up to near the end of the glacial flow the river was perhaps aggrading instead of eroding throughout its length in New York. A fifth factor is the lower power of the normal river, especially in New York. With the opening of the lower Mohawk valley for the escape of the glacial waters (34, plate 14) the Susquehanna was suddenly reduced to its present volume. Then for the first time since its preglacial days its work became wholly erosional. The relatively small volume, however, had a very long and wearisome task in clearing a graded channel through the coarse drift in the long stretch from Cooperstown to Waverly; and that work is not completed, for the river seldom touches rock but is flowing on the deep drift in its old and yet buried valley. The reader will now appreciate the complexity of these geologic problems.

Tilted Water Planes and Valley Gradients

In the figures 4–9 in the following pages the uptilted water levels are somewhat arbitrarily represented by straight lines, drawn through the more definite or better attested points of elevation, the line being intended to serve as a datum line, and to give suggestion of the approximate elevation in all localities. Measured elevations are indicated by an arrow point (/\), with the altitude given in feet above tide. In many localities the map contours show plains which agree closely with the datum lines.

The steep slope shown in the diagrams (figures 5–9) is partly due to the postglacial differential uplift of the land. Even when this is deducted there still remains, however, in many valleys a considerable total fall, which in some valleys, like the upper Susquehanna and the Chenango, may be partly explained by local drift dams and successive pondings of the valley waters and partly by the closing glacial flood. A much greater tilting of the land does not appear admissible.

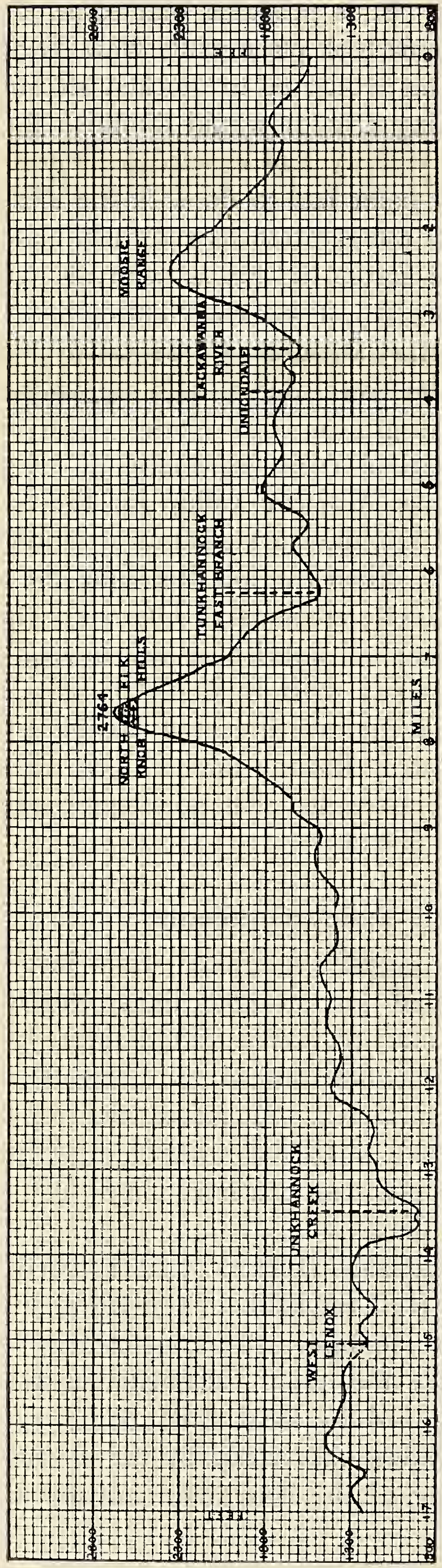


Figure 3 Profile, East and West, Across the Elk Hills of Northeastern Pennsylvania

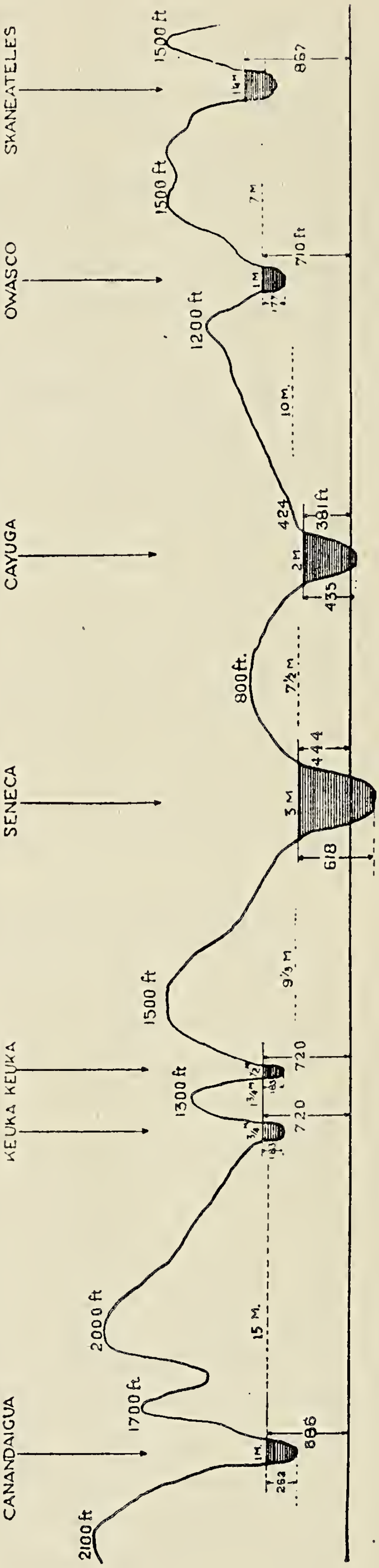


Figure 4 Profile East and West, Across Finger Lakes Valleys Showing Depth and Greatest Width of Lakes. Base Line is Sea Level

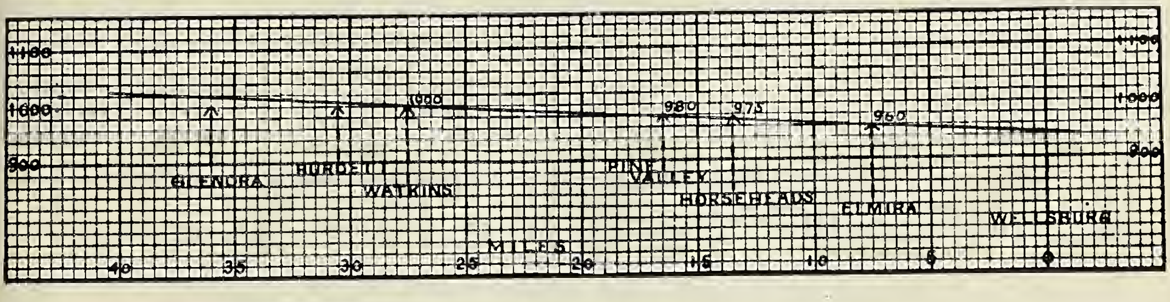


FIGURE 5 PROFILE, ELMIRA LAKE PLANE; WAVERLY TO GLENORA

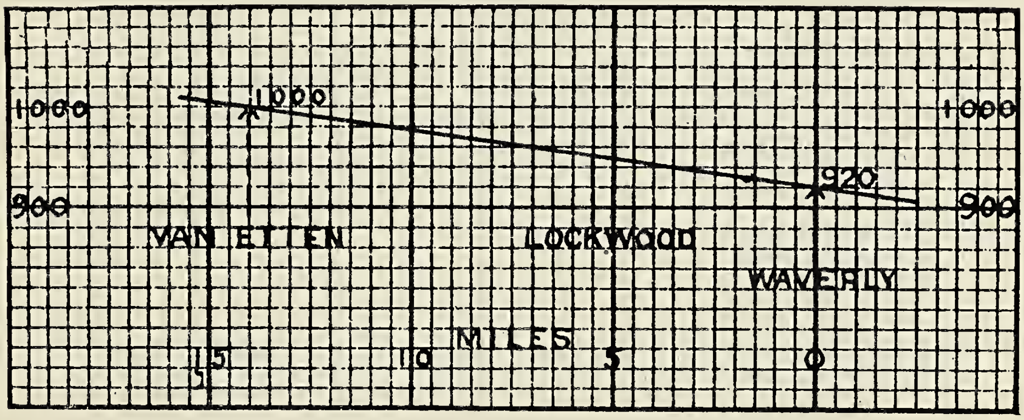


FIGURE 6 PLANE OF CAYUTA VALLEY WATERS; WAVERLY TO VAN ETTEN

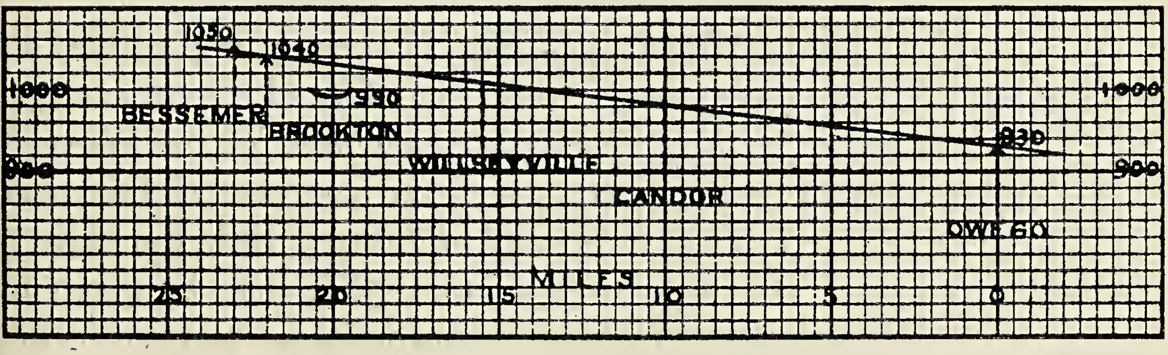


FIGURE 7 PLANE OF CATTATONK VALLEY WATERS; OWEGO TO ITHACA

The following table includes the data of the diagrams (figures 5–10) and the valley east and west of Waverly (*A* and *B*).

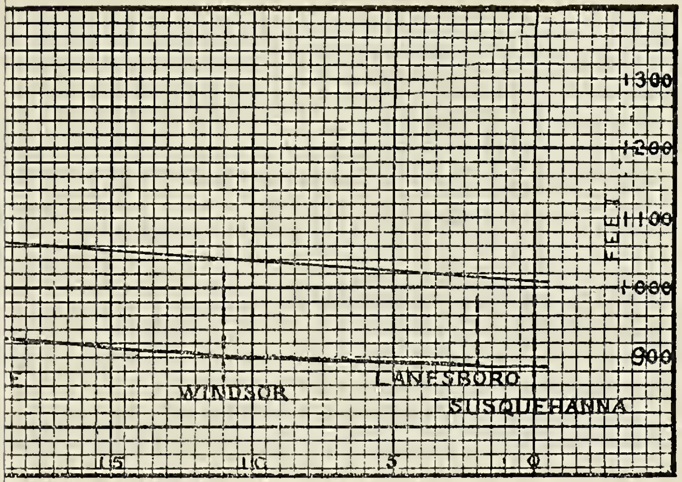
TABLE 10

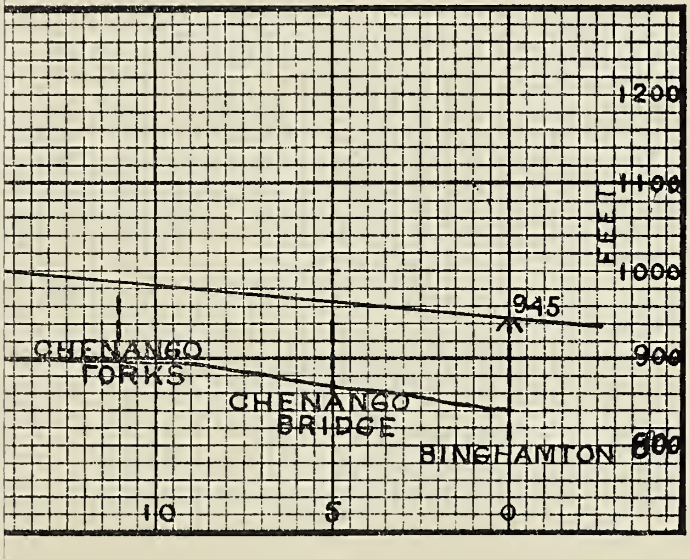
Altitudes and gradients (in feet)

EXAMPLES	VALLEYS AND ELEVATIONS	PRESENT RISE OF PLAINS	DIFFERENTIAL LAND UPLIFT	ORIGINAL RISE OF WATER SURFACE	DISTANCE IN MILES	ORIGINAL GRADIENT PER MILE
A	SUSQUEHANNA Waverly, 920 feet Binghamton, 945	25	30	—5	41	0
B	CHEMUNG Waverly, 920 Elmira, 960	40	5	35	18	2
5	SENECA Elmira, 960 Watkins, 1000	40	35	5	21	0
6	CAYUTA Waverly, 920 Van Etten, 1000	80	25	55	14	4
7	CATATONK Owego, 930 Brookton, 1020	90	30	60	22	3
8	SUSQUEHANNA Lanesboro, 1004 Cooperstown, 1250	246	140	106	80	1.3
9	CHENANGO Binghamton, 945 Bouckville, 1200	260	130	130	69	1.9
10	COHOCTON Corning, 960 Cohocton, 1310	350	35	315	35	9

It should be recognized that we are dealing with variable factors: inconstant water levels and deltas and sand plains with uncertain relation to the water surface. Precision is usually impossible, and some variation in vertical range must be allowed. For example, the figures for A of the table give a minus amount for the Waverly-Binghamton water plane. There are three sources of this small discrepancy: the level at Waverly may be taken a little too high, or the Binghamton one too low, or the land uplift may be given too high; or all three elements may be compromised. But the difference of 5 feet in 41 miles, considering the variables, is reasonable proof of original horizontality. In example 5 we have an opposite variation of 5 feet.

In the remaining cases the variation from original horizontality is too large to permit of continuous lake level; but in examples B, 7, 8 and 9 the explanation appears to be a series of lakes, or slack water, due to local drift barriers or to a glacial river of great volume. In examples 6 and 10 it is clear that we have only stream conditions.


1300
1200
1100
1000
900
FEET
WINDSOR
LANESBORO
SUSQUEHANNA
15
10
5
0


1200
1100
1000
900
800
FEET
945
CHENANGO FORKS
CHENANGO BRIDGE
BINGHAMTON
10
5
0

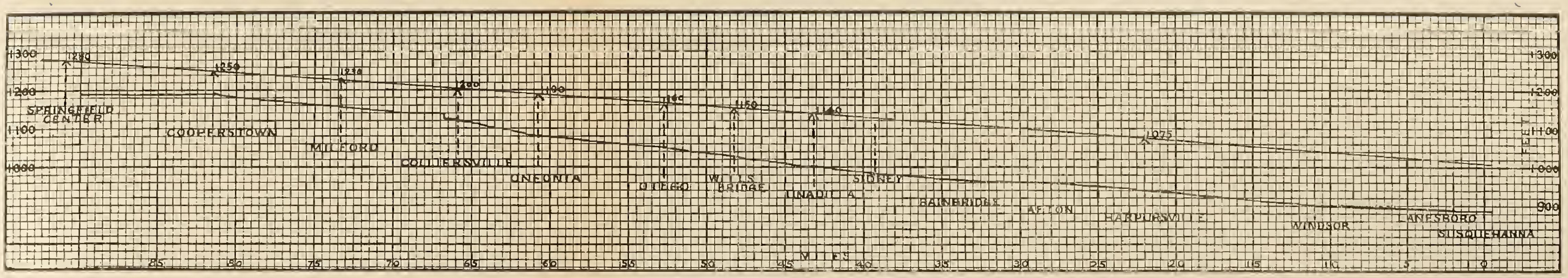


Figure 8 Plane of the Susquehanna Valley Waters; Lanesboro to Cooperstown

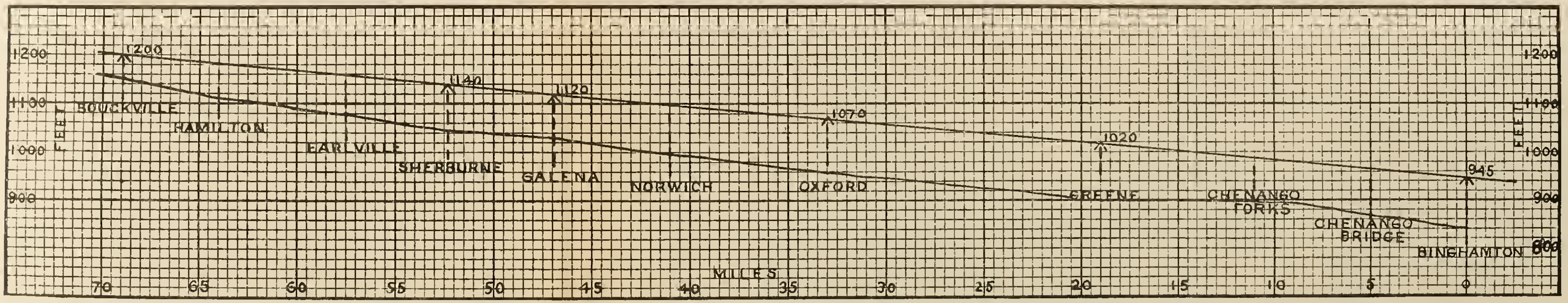
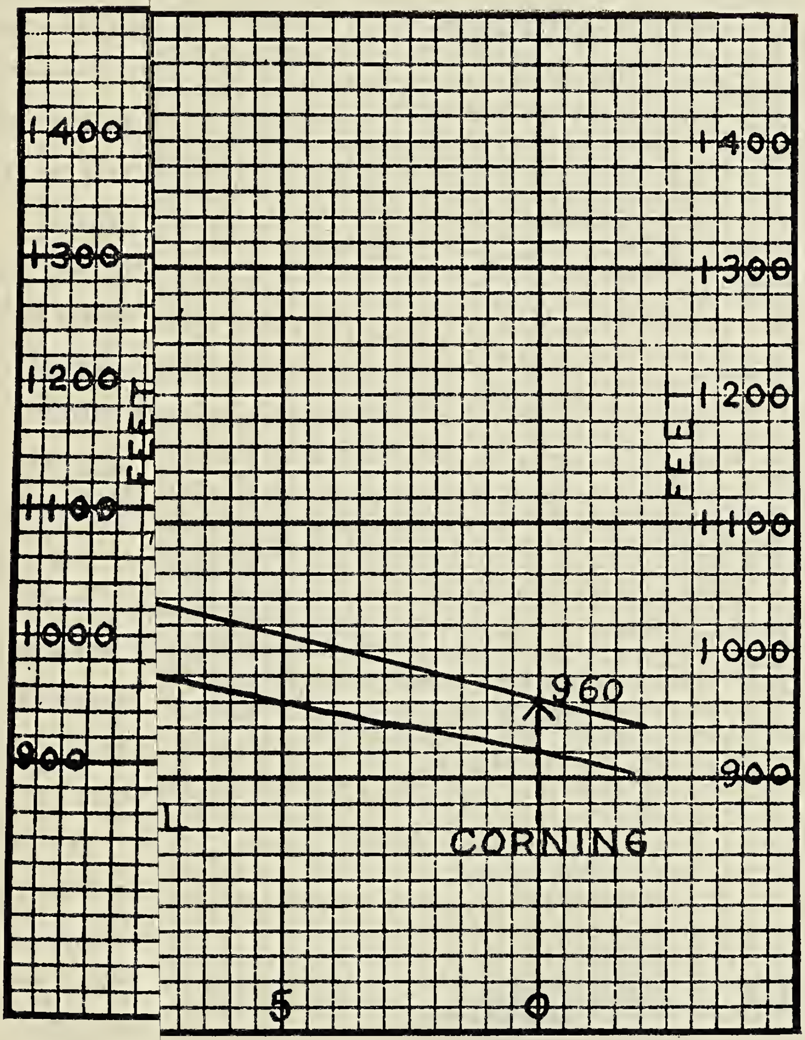


Figure 9 Plane of the Chenango Valley Waters; Binghampton to Bouckville


1400
1300
1200
FEET
1100
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900
L
1400
1300
1200
FEET
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1000
960
900
CORNING
5
0

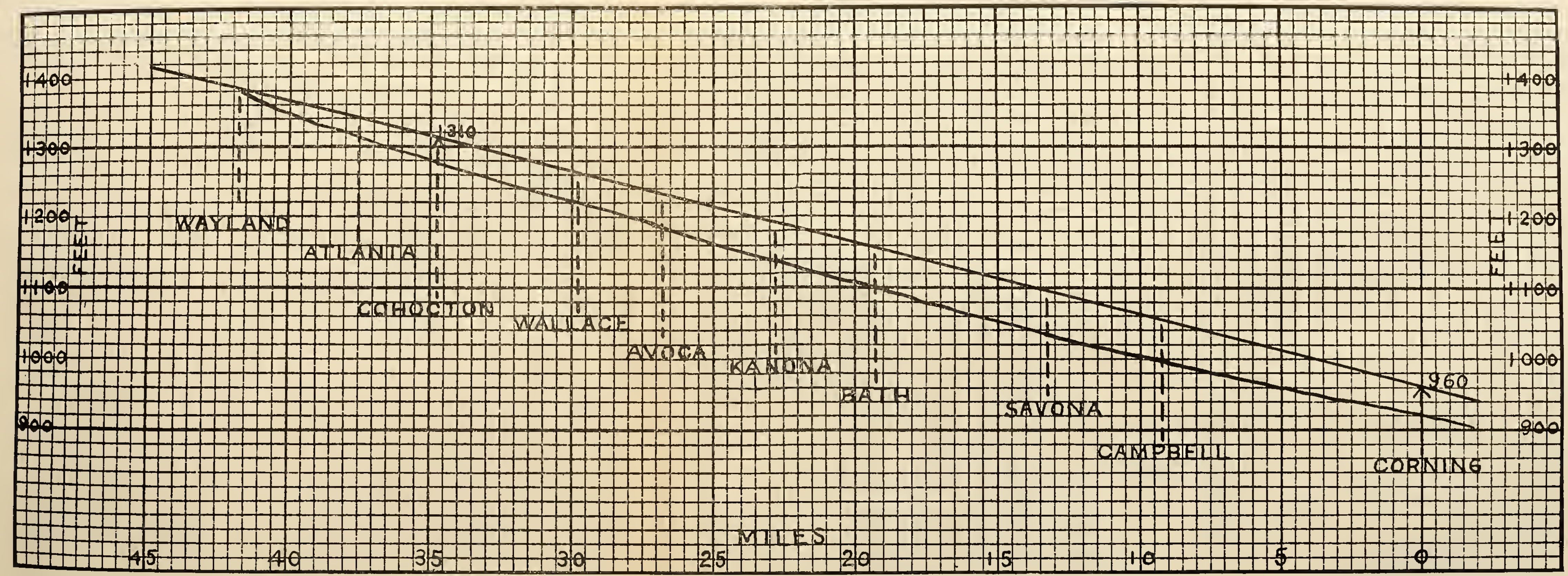


Figure 10 Plane of the Cohocton Glacial River; Corning to Wayland

DESCRIPTION OF THE VALLEY FEATURES

Classes and Forms of the Deposits

In the hope of making this writing of scientific interest and educational value to the people residing in the valley of the Susquehanna and its tributaries the following description is given with some detail and particularity for the several localities. The description will relate chiefly to areas adjacent to the cities and larger villages, where the descriptions may be readily verified and new observations made by the instructors and pupils of the colleges and high schools. No locality is fully described, as it will be more interesting and stimulating to the reader and student if he can make some discoveries of his own.

Some knowledge of the rudiments of geology and physiography on the part of the student must be assumed, but the following brief discussion of the origin and character of the valley deposits may be helpful.

Rounded rock materials, grading in size from bowlders down through gravel and sand to silt and clay, and lying with the assorted sizes more or less stratified, must always be recognized as the work of water. The coarseness or size of the particles is directly proportionate to the velocity of the water, from which it follows that silt or clay implies quiet or slack water, and fine sand requires very gentle flow. Every observant person familiar with the river valleys must have recognized such water-laid deposits along the valley sides, and high above any possible reach of present-day floods. The ancient deposits of sand and gravel usually form level stretches, as plains and terraces, and are conclusive proof of either stream or lake at the height of the deposit. The study of these deposits in their geologic and time relations is not surpassed in disciplinary and cultural value by anything taught in the schools.

In many localities, especially on the higher ground or above the reach of the higher valley waters, but sometimes in the valley and more or less buried in the river deposits, the glacier has left deposits of ice-laid materials, which should be discriminated from the water-laid. The latter are stratified and in assorted sizes. The former are unassorted stuff of all sizes, shapes and kinds of material, usually containing rocks from regions far northward, even crystallines from Canada or the Adirondacks. When this glacial-drift, or till or bowlder-clay, is heaped in irregular masses, hills or knolls, it constitutes a moraine, and represents at least a relative standstill of the receding ice margin, and should be carefully mapped.

The water-laid deposits, the sand and gravel, will also contain all kinds of harder rock, the same as the till, because much of the river-borne drift was contributed by the glacier which gathered some of it in the far north. Discrimination from ice-laid deposits relies on structure and not on composition.

The water-laid valley deposits fall into several groups, according to their origin and relation, and the recognition of the different kinds in field study will be found interesting, and commonly not difficult.

1 **Kame and kame-moraine.** These are knolls or mounds, small or large, built by streams pouring out of the ice sheet into quiet water. The materials are poorly assorted, with obscure or irregular bedding at variable inclinations. Kames are of the nature of incipient, short-lived deltas. They are often associated with eskers, the latter being coarse deposits in the beds of the subglacial streams which fed the kames. Kames are essentially morainal, belonging to the frontal deposits of the ice sheet.

2 **Eskers.** As above noted, these are the singular, sinuous and steep-sided ridges of coarse gravel or cobble, usually lying along the bottoms of valleys. They were built of the laggard materials in streams which were flowing at the bottom of the ice sheet, near its margin, and which were supplied with more coarse detritus than they could carry. The best example seen in the Susquehanna valley lies west of Lanesboro, curving around to Susquehanna village (plate 33). Another of great length lies in the narrow valley of Dudley creek, between East Richford and Center Lisle (Harford sheet), and carries the highway for long distances. Eskers are peculiar phenomena, and before the science of glaciology they were unexplainable.

3 **Delta plains.** When these were laid at the ice front by the outwash of the melting glacier into lake or sea they would normally slope away from the ice front, and the ice-ward margin might blend into the glacial stuff, and it might have the irregular form of the ice contact. When high plains occur at the mouths of tributary valleys they represent the deltas of the side streams, and will naturally grade into the high flood plains of the latter. The surface of large deltas of coarse material may be higher than the water level of the receiving body; but the front of a delta of fine material, as fine sand or silt, was beneath the surface of the standing water.

4 **Lake plains.** These are level stretches of sand and gravel, built usually along the margins of the standing water. The material was contributed from glacial outwash or by contribution from land wash and inflowing streams. They may have different levels, or terraces, if they lie in a lake area of falling water levels. They grade into the flood plains of the river and its tributaries, from which they may not always be distinguished. The present plains are only fragments of the original plains.

5 **Flood plains of the river valley.** These are the more common and conspicuous of the valley features. Along the valley sides they form benches or terraces which represent the slowly falling levels of the river. In areas of lakes, like the Elmira and Binghamton lakes, they include only the lower plains. In a stretch of the valley where the slope of the plains up stream is greater than can be due to the land tilting they must represent the border deposits of the river; the Cohocton, for example.

6 **Flood plains of the side valleys.** The tributary waters were graded to the falling waters in the main valley, except as local lakes were held in by drift dams. In the larger valleys, like the Unadilla, Chenango or Otselic, it is difficult to say if certain higher plains are of lake or stream genesis. In those of very steep grade, like the Cohocton, the plains must be flood plains.

All the conspicuous phenomena of the valleys are related to the waning and removal of the ice sheet. The only deposits which can possibly be attributed to the invading ice, or the time of the oncoming of the glacier, are some of the deepest, hard, blue tills, which are found in some deeply eroded stream channels. It is possible that some of the deeper gravels in the valleys may be related to the outwash of the advancing ice front, but such have not been recognized.

The important and most interesting element in the field study of the water deposits is the determination of the full height or summit level of the lake or slack waters. This is the most difficult, yet on that account the most instructive. As the waters were slowly drained away, the detrital materials were swept down to lower and lower levels, and the later and inferior plains are commonly the more conspicuous. In no one locality should the highest visible plain, taken by itself, be confidently regarded as the summit water level. In many localities the highest plains which appear to mark the highest stand of the water are found to lie below the true summit, as proven by yet higher plains in nearby localities. The summit may be approximately determined by finding the altitudes along considerable stretch of the valleys. Sometimes the little deltas of weak streams, or even wet-weather runs, on the sheltered valley walls, are excellent criterions.

In the following pages the figures given for the higher plains must not be understood as absolute. They are subject to possible correction. The approximate summit water level for any locality may be found from the profiles (figures 5–10).

A very interesting fact is that nearly all the cities and villages in the Susquehanna valley and the larger tributary valleys are built on the old gravel plains. They owe their location and often their expansion to the continental glacier.

It must be recognized that the rock hills and the broad valleys are all preglacial, dating from Tertiary time.

Elmira and Binghamton Lakes

Plates 10–15

Two lakes existed in New York which were rivals of the Wilkes-Barre-Scranton lake in Pennsylvania. These lay in the Susquehanna and Chemung valleys, along the south line of the State.

The Binghamton lake filled the Susquehanna valley from Towanda up to Great Bend, with a short arm up the Chenango valley to Chenango Forks. The cause of this lake must have been moraine barriers in the narrow stretches of the winding valley south of Towanda.

The Elmira lake was held at a somewhat higher level, evidently by drift barriers in the east and west stretch between Waverly and Wellsburg. The standing water extended from Wellsburg to Corning, with a long north branch in the Seneca Valley. At the west end the lake plains grade imperceptibly into the old river flood plains of both the Cohocton and Canisteo valleys.

In the earlier study of the large area it was supposed that a single water body occupied both the Binghamton and the Elmira districts; but close examination of the detrital plains, in their altitude relation to land uplift, requires the separation into two lakes. As the general trend of the lakes was east and west the area was not greatly tilted by the postglacial land uplift, but the deformation was sufficient to clearly show and to be useful in translating the history. For example, on account of their more southerly location the plains at Great Bend are 25 feet lower than the Binghamton plains, but at Elmira and Corning, which are farther south of the Binghamton isobase than Great Bend, the plains are 20 feet higher than at Binghamton (figure 2).

These lakes were too narrow to admit of heavy wave work and production of conspicuous shoreline features, and we have to depend for the elevations of the water surfaces chiefly on the detrital plains and deltas, which are commonly below summit level.

These lakes fell away as the holding barriers were slowly eroded. It is possible that the Binghamton lake was extinguished when the closing glacial flood (plates 7 and 8) swept through all barriers.

Corning District

Corning sheet, plate 23

The western limit of the Elmira lake is found here. The wide plains, at 920–30 feet, which carry the lower part of Corning city and North Corning and Painted Post represent the lower levels of the lake. Above Painted Post up both the Cohocton and Canisteo valleys the plains become the old flood plains of the swollen rivers contemporary with the lake. The rivers have not greatly intrenched the old plains, for the Chemung has elevation of 920 feet at the point of its origin, and 900 feet a mile below Corning. The channels of the Canisteo and Cohocton, cut in their old flood plains, are still quite shallow.

Gravel bars of wave construction must be very rare in the lake area, but the long stretch of open water on the east toward Big Flats permitted wave development and the piling of a gravel bar on the west side of the valley below Corning. This is southwest of the Protestant cemetery, along the west side of the Erie railroad. At the north end of the bar by the corner of the cemetery an old gravel pit shows the nature of the deposit. The bar terminated here in a wave-eroded cliff on the steep hillside. The elevation of the bar is 935 feet. It indicates a fairly steady level of the lake for a time with water 35 feet deep.

Elmira District and Seneca Valley

Elmira, Waverly, Watkins sheets, plate 10

In the Elmira region we have the most extensive plains of the whole drainage area of the Susquehanna, and a complex and interesting history. The wide valley, now deeply filled with detritus, between Big Flats and Horseheads was in preglacial time the course of the Chemung river, while the extensive plains north and south of Elmira and north of Horseheads are filling in the supposed ancient valley of the Susquehanna (plate 5). The narrow valley now occupied by the Chemung river from Big Flats to Elmira is a new course of the river into which it was forced by the ice blockade. It is a fine example of recently diverted river flow. This Elmira sheet is one of the most interesting physiographic maps in the United States.

The new valley of the Chemung, some 7 miles in length, must have been in Tertiary time the valley of one or two small tributaries of the great rivers. During the ice advance the Chemung was compelled to take and deepen this small valley. Then it was overridden by the glacier and partly filled with drift. When the ice front in recession passed over the district the Chemung was compelled to permanently follow this course, but it has not been able to excavate it deeply.

The spread of the Elmira lake is fairly indicated by the white areas of the map, but the plains are inferior to the summit level of the lake. The plains represent a part of the load of detritus swept into the lake, from the west by the glacial Chemung and from the north by the outwash of the ice sheet. The detritus was spread and smoothed by the falling lake waters and by the earliest flow of the rivers. Below Elmira the Chemung is flowing on the lake filling which was recently its flood plains. At Wellsburg the river by the map is 800 feet above tide. South Elmira is on ground at 840–80 feet. Under Elmira the plain rises from 840 to 900 feet, and at this level spreads north to Horseheads and west to beyond Big Flats. The summit level of the early lake is shown by the weak shore line features about the valleys, and especially by the deltas of the smaller streams built in the lake. The west side of the valley at Elmira and north to Horseheads will afford good data. Along the steep valley wall east of the city are conspicuous benches built in the waters by the storm-wash from the high slopes (plate 29). The best locality for study of the sand plains and water level is the extensive plain north of Horseheads and the shore line between the north branch of Newtown creek and Catherine creek, where the combined forces of the streams built a splendid delta plain. At the road corners where Catherine creek debouched into the lake is the north head of the gravel delta, with altitude by the map of about 975 feet. Farther north, at Pine Valley, heavy, conspicuous plains lie on both sides of the valley up to about 980 feet. The tilted water plane falls to about 960 feet at Elmira. The summit level is seen at Woodlawn cemetery and Carrs Corners, where Heller creek and Hoffman brook swept in their detritus. The city is built on inferior plains, the business portion on the abandoned Chemung flood plain at about 840 feet.

Another interesting glacial feature is found in the Elmira district, and shown in plate 10. This is a local glacial lake held in the Newtown valley at Breesport and Erin. The last phase of the glacier in the district was a lobe or tongue of ice lying in the large valley over Pine Valley and Horseheads. This ice lobe closed the Newtown creek valley and the waters ponded in the "Breesport glacial lake" were forced south through Baldwin creek. The head of the outlet channel is a mile and a half south of Breesport, with altitude about 1160 feet. A later and short-life pass seems to have been behind the hill northeast of Horseheads at 1100 feet. Below Breesport the creek has eroded its channel in the lake filling, but this rises to 1260 feet at Erin.

The classes in science of the college and high schools should find instructive and fascinating work in tracing the glacial phenomena, in determining the precise summit lake level and in discovering the details of the glacial history. Many very interesting and curious features may be found. For example, the basins in Eldridge Park are "kettles," produced by the late melting of detached ice blocks which had been buried in the detritus of the plain. Other kettles lie 2 miles north of Horseheads. The most important investigation is the measuring of the depth of drift in the valleys, and discovery of the altitude and form of the preglacial rock valleys.

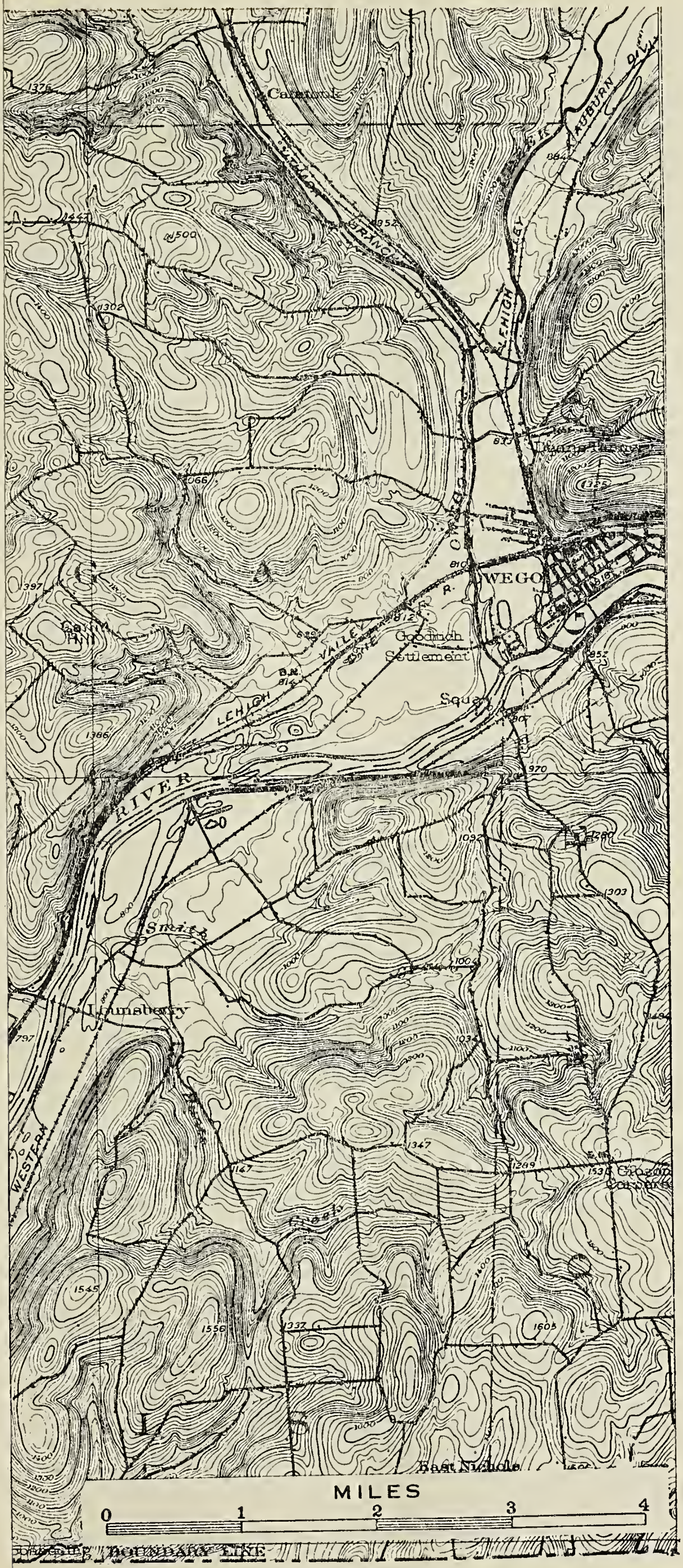
As the ice lobe melted away it was laved and followed by the highest waters of the Elmira lake, which eventually extended into the Seneca valley for some distance north of Watkins. At Watkins the level of the Elmira lake is seen at the head of the famous glen, by the station of the New York Central railroad, where the delta of Glen creek has an altitude of 1000 feet. Eight miles farther north, and southwest of Glenora, Big stream and Rock stream have combined to build elegant delta plains. The highest terrace is south of a road corner, on land of Willis Barber, with elevation of 1000 feet. The heavy benches below, beginning at about 965 feet and falling to 900 feet belong to the successor to the Elmira waters, Lakes Watkins and Newberry (30, 33). Other yet lower terraces correlate with subsequent lakes, Hall, Vanuxem, Warren and Dana.

On the east side of the valley the village of Burdett stands on delta plains rising to 1000 feet. The village of Odessa, 5 miles southeast of Watkins, is built on broad gravel plains at 1020–50 feet. It will be noted that this level is above the plane of the Elmira waters, while the Burdett and Glenora levels are below. The Odessa gravels were laid in the local "Odessa lake" which was held up by the Seneca valley ice lobe. The higher waters of this Odessa lake found outlet near Alpine to Cayuta creek, at 1160 feet; and the plains at Odessa village must represent escape of the waters along the steep valley wall 3 miles southwest, into the Elmira waters that were displacing the Seneca ice lobe. This relation of ice-dammed waters in embayments on the sides of the larger valley suggests the complexity of the phenomena, and the caution to be observed in study and correlation of the water levels.

We have noted the discrepancy between the levels at Watkins and Glenora. A glance at the profile (figure 5) shows that the Watkins Glen level lies in the plane of the summit levels at Elmira and Pine Valley, but that the Glenora and Burdett terraces are somewhat lower. The explanation illustrates the necessity of knowing the events or steps in the glacial history. During the life of the Elmira lake the drift barriers which were holding up the lake were being lowered, with eventual draining of the lake. It appears that the Seneca valley ice lobe had diminished so as to let the lake waters penetrate alongside the ice tongue as far north as Watkins while the lake retained nearly its summit level, but that by the time the waters had penetrated to Burdett and Glenora the water surface had fallen; and when the lake had lowered to near the valley bottom above Horseheads so as to produce river flow across the deposits in the Pine Valley-Horseheads district a new and distinct series of lakes were held in the Seneca valley. The immediate successor of the Elmira waters in the Seneca valley was Lake Watkins. By further recession of the ice front in central New York Lake Watkins penetrated into the Keuka valley on the west, and into Cayuga valley on the east, and the much expanded waters were named Newberry (28). The later outflow of Newberry cut the definite channel which appears some 2 miles above Horseheads and is followed by Newtown creek to its junction with the Chemung river. In the downcutting through the lake deposits by the Newberry outlet, the Horseheads river, terraces were shaped on either side of the channel. Two benches on the east side below Horseheads are conspicuous (plate 29).

In the earlier papers by the writer the existence of the high waters, Elmira lake, preceding Lake Newberry was not recognized, as the Susquehanna valley history was unknown. In 1903 M. L. Fuller noted the complexity of the features (27); and the Horseheads features were also mentioned by Tarr (15).

BULLETIN 256 PLATE 11



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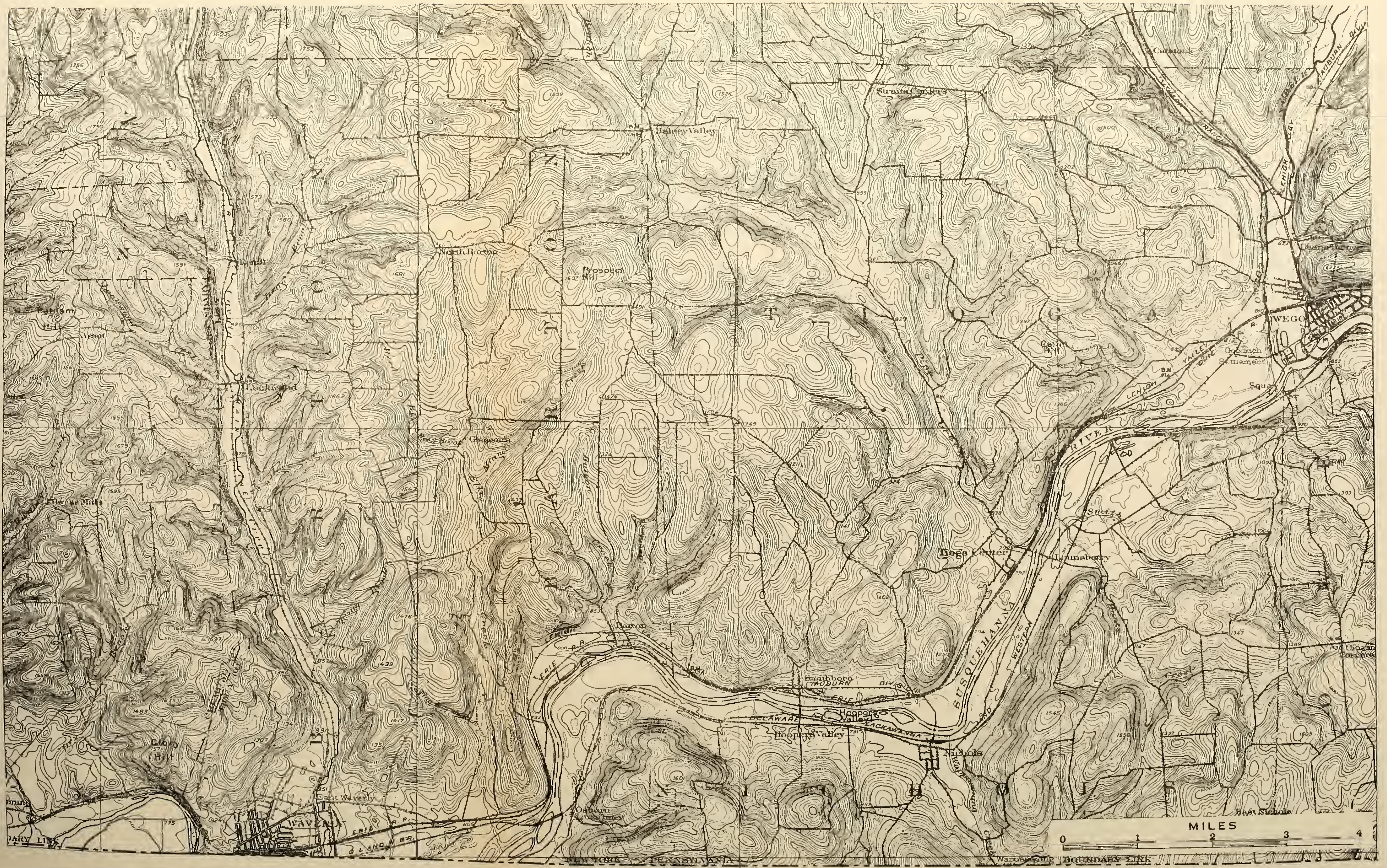
BULLETIN 256 PLATE 11



Waverly-Owego District

Waverly District

Waverly sheet, plate 11

This district is the most critical in the history of the Susquehanna river, but unfortunately the river and nearly all the valley features lie in Pennsylvania, and we have no topographic maps. The villages of Sayre and Athens stand on the extensive low plains that occupy all the space between the Susquehanna and Chemung where they are reluctant to join their waters. Waverly lies mostly in New York, on the higher northern edge of the valley plains, with elevation along the main street of 835 feet, and rising to 900 feet in the north part of the village. At the entrance to the cemetery northwest of the town the delta plain is 920 feet. West of the village and close west of the golf ground a poorly developed gravel bar stands at 910 feet. Northeast of the village the plain carries many kettles; while eastward for 3 miles the valley holds a kame-moraine.

It might be a disappointment not to find a heavy delta here, where Cayuta creek poured a glacial flood into the Binghamton lake. The explanation is that the glacial drainage lodged its detritus farther north, in the Van Etten district (plate 13), and that the lower part of the Cayuta valley was buried in the lake waters. The lake deposits in the narrow valley have nearly all been swept out by the creek, but remnants of the side deltas are seen at Lockwood, Reniff and other points.

Spanish hill, southwest of the village, stands out boldly as an isolated mass, with its summit about 1000 feet elevation. Its surfaces are glacial and lake deposits, and on the north side it carries a kame-moraine of high relief with deep kettles. Until its interior structure is known, whether rock or drift, its significance in reference to the valley history can not be known. If it has a core of rock it is an outlier of Chemung strata, and has been the witness of the shifting and reversal of flow of the great river. It may be well to epitomize the history of this important locality.

It is possible that in early Tertiary time the river flowed south at this point, as today. We do not know. It may be that when the Susquehanna had been brought here the path around to the Seneca valley was more attractive. It is almost certain that it took the Seneca valley course in the late Tertiary period (plate 5). Then it was joined here by a small stream that headed somewhere in the Towanda region. When the implacable ice sheet had conquered New York so as to block the Mohawk valley, the tremendous glacial flood of the Susquehanna and the Chemung united here for the eroding plunge southward. When the ice margin lay at this locality the erosive effects of ice and water combined might have been unusual, but are unknown. Then for tens of thousands of years the deep ice sheet scraped the region, sandpapering the hills and pushing drift into the valleys. When the glacier was overcome by climatic reaction and passed off New York the drama of river and glacier was reenacted in reverse order.

At Sayre the Susquehanna is on rock; but this is on the east edge of the great valley, and so has little value as to the depth and location of the Tertiary drainage. All possible data with reference to the depth of drift, or rock altitude, in the valleys should be collected if we are to know the true river history. When the Sayre and Towanda topographic sheets are published it may be possible to add some interesting elements to this sketch of the important district.

Owego District

Owego and Apalachin sheets, plates 11 and 12

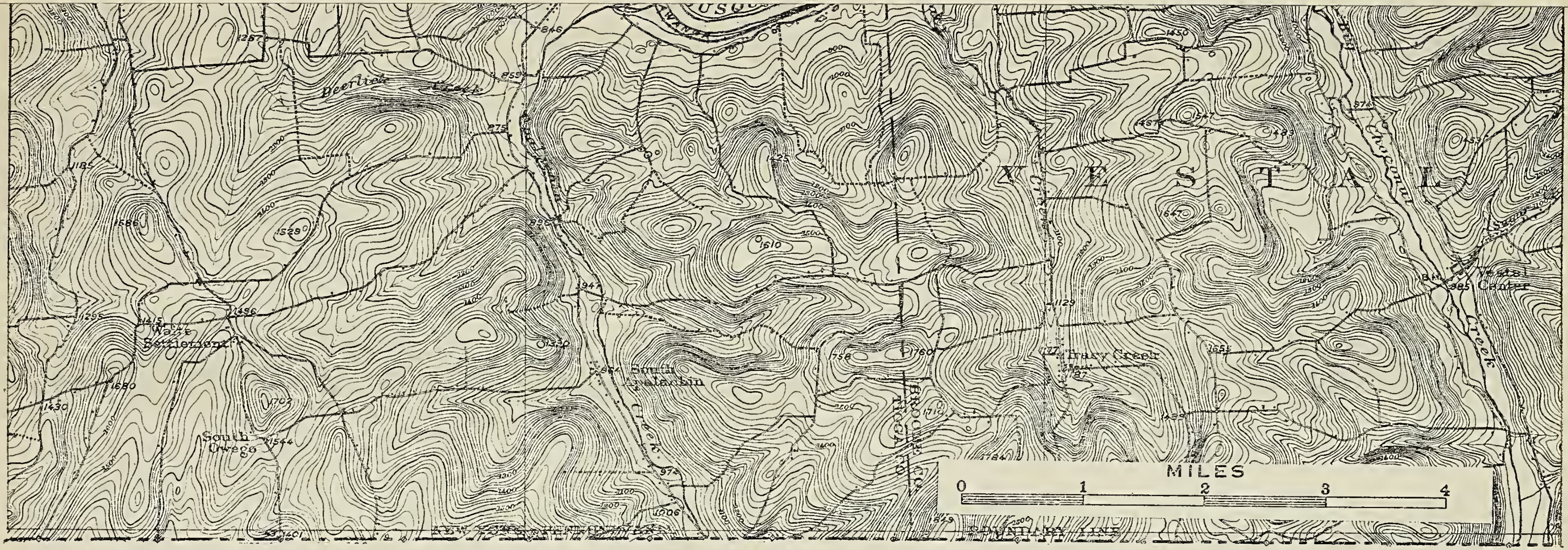
From Waverly to Owego the river valley exhibits no unusual features, but good display of the lower lake plains, especially at or near Barton and Lounsberry, and the terracing by the intrenching river. The river is flowing in the lake deposits, with a gradient of about 2 feet a mile. It has not developed good meanders, and is busy with transportation instead of erosion.

The summit level of the lake waters is not evident and has not been sought in this stretch of the valley, but going south from Nichols up the Wappasening creek the lake plains are handsome, and the lake summit is found 8 miles up the flooded valley, close to Windham Center. At the village the plain is somewhat above the lake surface and represents the creek delta.

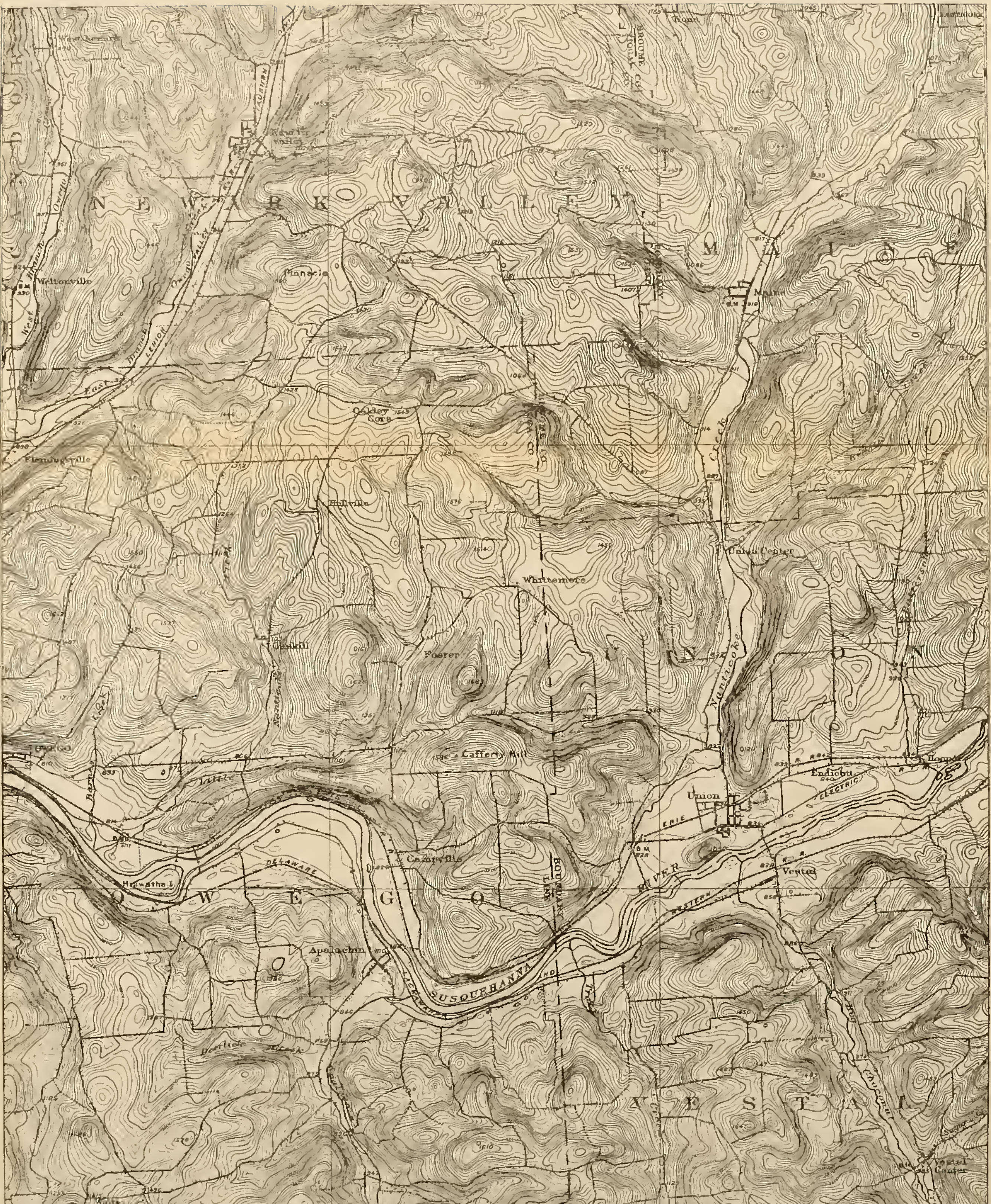
At Lounsberry is a good plain at 880 feet, and a delta occurs at the mouth of the ravine on Hunts creek, a mile east of the railroad station. Three strong bars lie on the delta, extending north and northeast, with elevation approaching 900 feet.

Two miles north of Lounsberry are a number of large kettles, indicated on the map. Like many similar basins they prove the persistence of the buried ice blocks while the deposits remained under water.

At Owego is a wide section of the valley, at the junction of Owego creek, and the river was forced to the south side by the flood and detritus of the Owego and Catatonk creeks. The lower lake plains, although greatly eroded, are conspicuous, but the higher water has



Union–Endicott District



Union–Endicott District

left slight evidence. The city is on the low plain, 800 to 820 feet. The plateau at the Goodrich Settlement has summit elevation of about 850 feet. Along the sides of the valley, especially on the west, evidences of standing water have been found up to 880 feet. The theoretic altitude of the summit level here is about 930 feet. This affords good illustration of the truth that a single locality is not dependable for summit water level, and that negative evidence is not conclusive.

The east and west branches of Owego creek were flooded by the Binghamton lake, and the valleys hold a fine display of terraced plains. Plate 30 shows the strong terraces at the junction of the branches, near Flemingville. The village of Newark Valley (plate 12) is on a plain 960–80 feet. Three miles north the 1000 feet contour lies across the floodplain, while at Berkshire, 6 miles north, the plains are 1060 feet. The present slope of these stream plains is at least 13 feet a mile, and with liberal deduction for the postglacial uplift they must have had an original slope of 10 feet a mile.

The Catatonk valley brought to the Susquehanna the overflow of the ice-bound waters of the Cayuga valley, Lake Ithaca, but this is considered in the next chapter.

Between Owego and Binghamton are two southern tributaries, Apalachin and Big Choconut creeks, and Nanticoke creek from the north. The river tributaries from the south, having northward flow, have a different history from the northern tributaries. The latter were flooded by the outwash from the ice sheet and filled with detritus, or " valley train " drift, and consequently these streams carried detritus into the Susquehanna lakes. On the contrary, the southern valleys were blocked by the ice sheet and their ice-bound waters, local glacial lakes, had their volume fixed by the lower passes for southward escape, and the detritus from the ice sheet was dropped in the local lake. The only detritus which these southern streams have carried into the main valley is the moderate load derived from the erosion of the present channels. Of course these southern valleys were flooded by the Susquehanna waters, but the stream deltas are some distance up the valleys, as already noted for the Wappasening.

The glacial lakes held in the Apalachin and Choconut valleys have been mentioned and their outlets located in an earlier chapter, page 27.

In the Apalachin valley the Binghamton lake extended about 3 miles, where the plains are over 900 feet. In Big Choconut valley the lake waters reached up the valley only a couple of miles, judging from the Apalachin sheet (plate 12). A mile south of Vestal the road lies on a bench at 900 feet.

The Nanticoke valley has not been examined, but the map suggests that the lake must have reached to above Maine village.

Cayuta, Catatonk and Cayuga Valleys

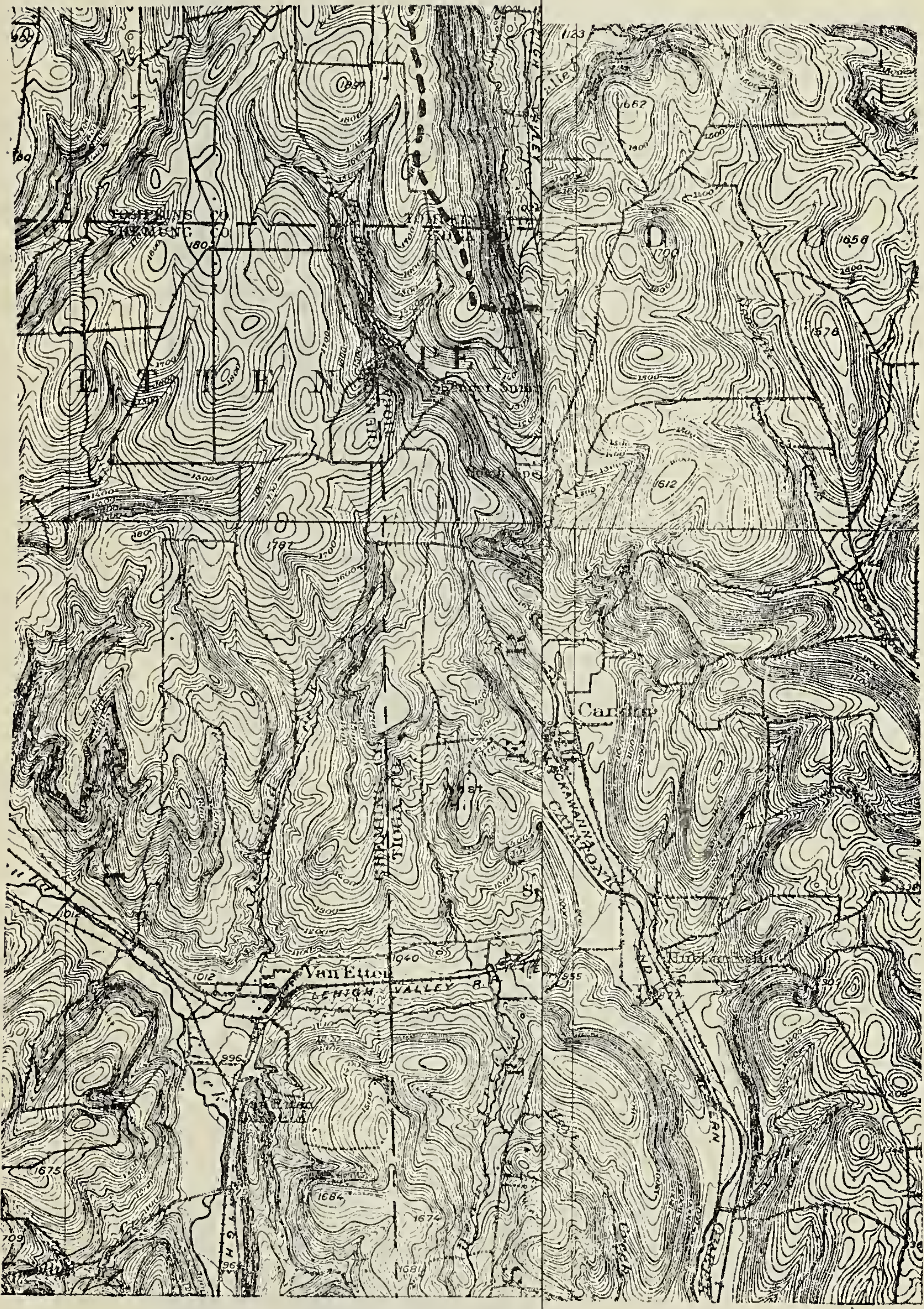
Ithaca, Waverly, Dryden, Owego sheets, plates 13 and 14

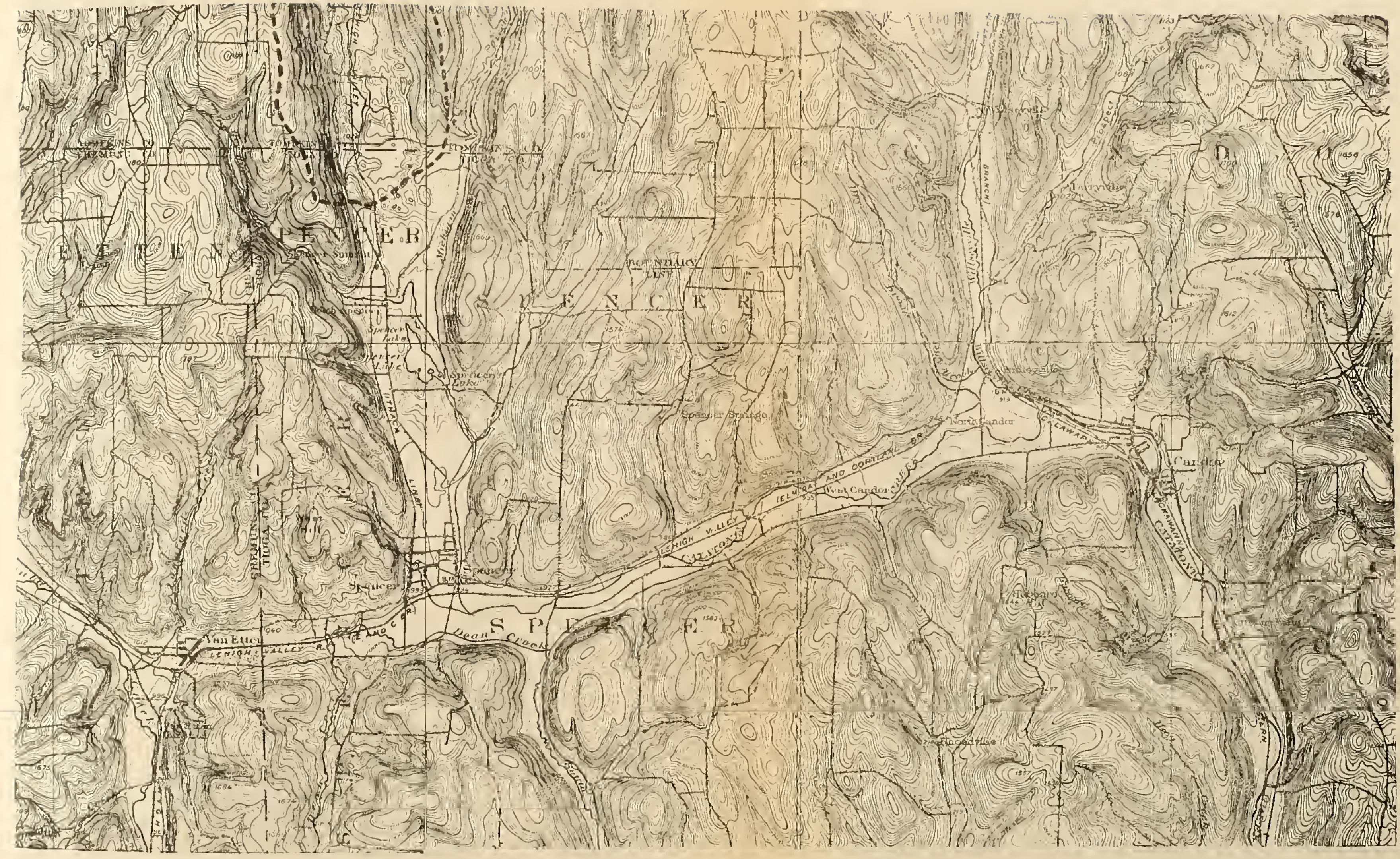
This district has a complex of valleys and an involved glacial drainage history. The net of valleys in the larger area is shown in plate 3. This chapter carries the story northward to Ithaca, for just as the lake waters chased the waning ice sheet into the Seneca valley, so the high water, perhaps held yet higher by drift barriers, pursued the retreating ice front into the Cayuga valley.

The south-leading valleys of Cayuta and Catatonk were partially blocked by ice and stream drift, which lifted the waters of the valleys at Spencer and Candor to yet higher levels, and these high waters reached into the two south forks of the great Cayuga valley. The water planes are shown in figures 6 and 7.

A mile east of Van Etten is the flat, swampy divide between the Cayuta and Catatonk drainage. Evidently this divide was not covered by the standing waters, at least not for any length of time. The altitude of the col is under 1020 feet, while the definite sand plains at Van Etten on the west and Spencer on the east are 1000 feet. This gives a limit figure for the ponded waters in the two upper valleys toward Cayuga.

The district of Spencer and North Spencer, the head of Catatonk creek, has exceptional interest in glacial geology. A heavy moraine was piled here, extending from a mile north of Spencer village to within a few miles of Ithaca, a stretch of about 12 miles. The outlet channels of the West Danby glacial lake (28) lie across the indefinite divide above North Spencer, with elevation 1040 feet. Very interesting features of lake and stream work are found on the east wall of the valley up to 1100 feet. Within the space of 2 or 3 square miles in this locality are found all the variety of deposits and topography associated with the removal of the glacier. Here are till-moraine and kame-moraine, high-level drainage channels in both drift and rock, deltas in lateral ice-dammed waters, and by free flow into open-lake waters. The history of the ice-front recession in the Cayuga valley is on record here from the time of the glacial outwash and the building of the Spencer moraine,


SCHUYLER CO
CHEMUNG CO
VAN ETTEN
Van Etten
Cayuta
Lockwood
Spencer Summit
LEHIGH VALLEY R.R.
TIOGA CO
CATATONK
1797
1612
1656
1578
1700
1662
1675
1684
1674
1681
1012
996
1640



Van Etten–Spencer–Candor District

The broken line marks the divide between northward and southward flow

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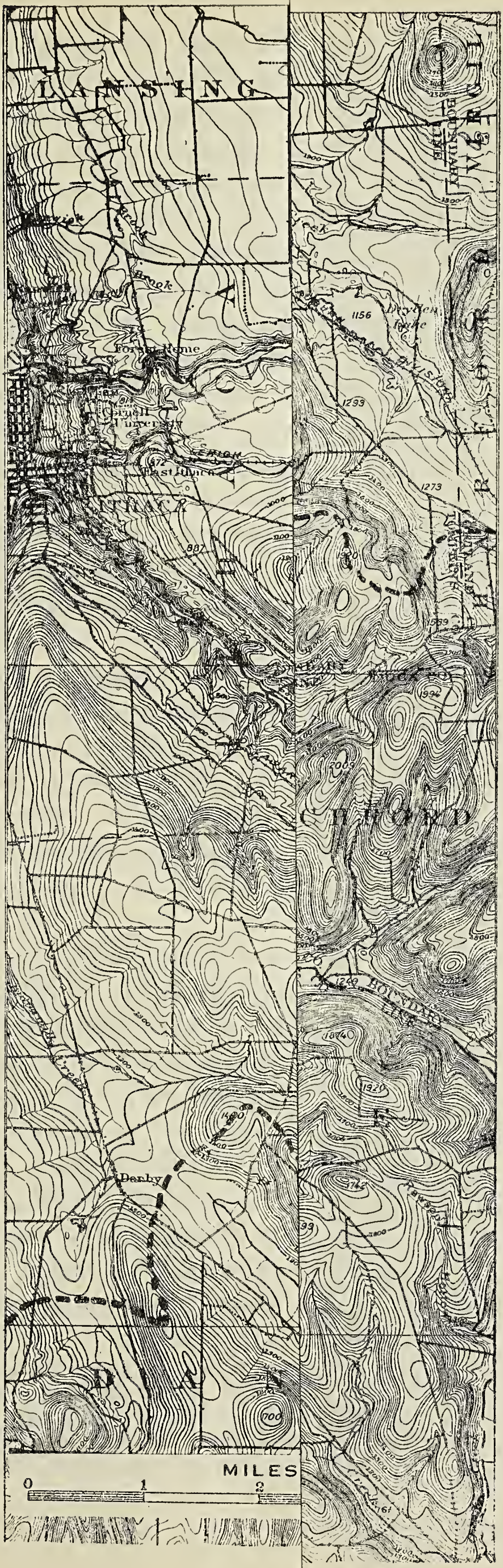
TIN 256 PLATE 14



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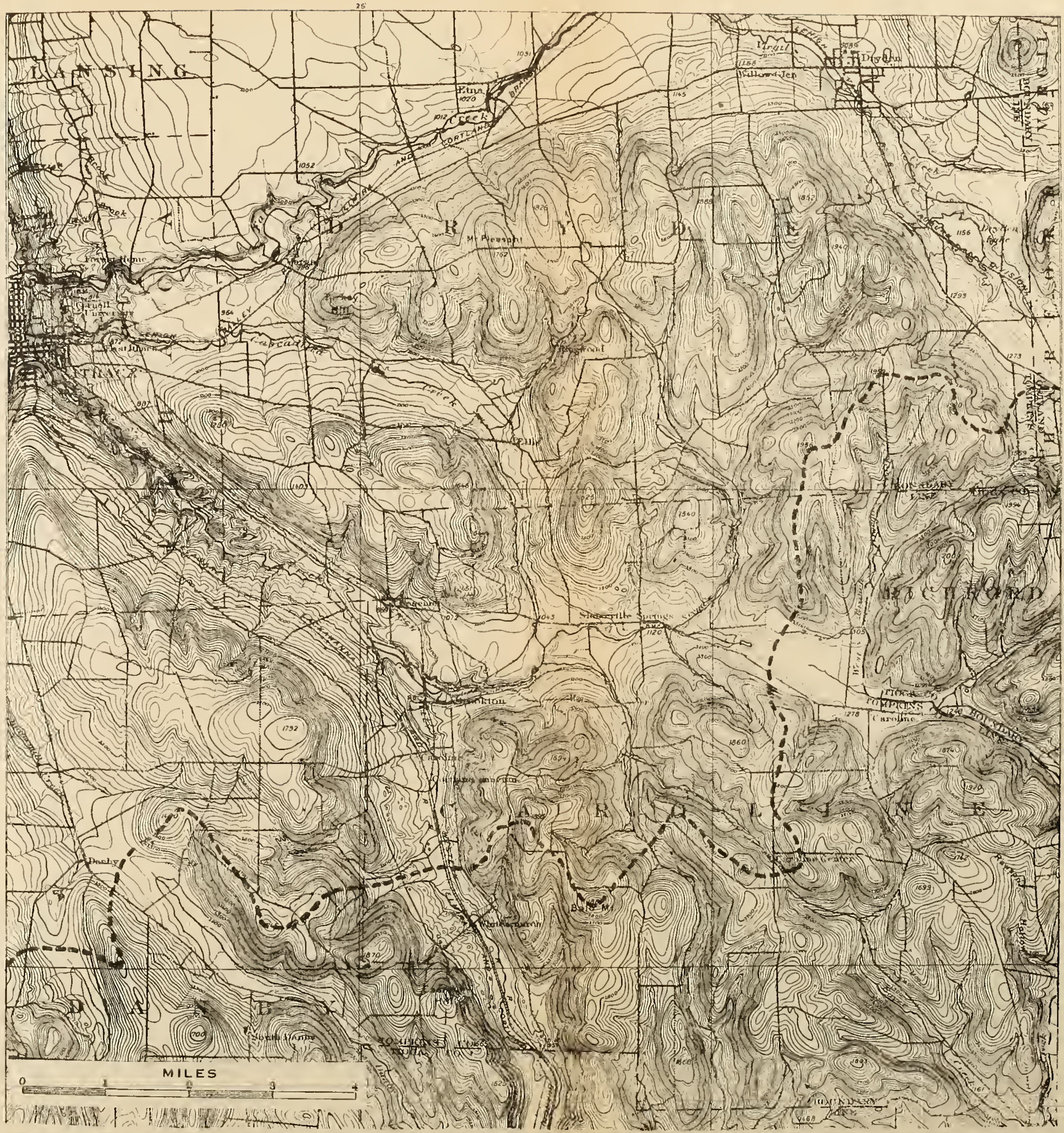
BULLETIN 256 PLATE 14



Ithaca–Brookton District

The broken line marks the divide between northward and southward drainage

through the life of the West Danby lake and until its extinction, with the establishment of the present drainage. This complex of geologic phenomena affords an exceptional opportunity for intensive study and precise mapping of a small area.[1]

The outflow of the glacial waters in this west fork of the Cayuga valley, the West Danby lake, past North Spencer and Spencer, was eastward and then southward by the Catatonk creek to the Susquehanna water at Candor and Owego (plate 13).

The east fork of the Cayuga valley now claims attention, and here we find another interesting district with involved history (plate 14). Willseyville creek, which joins the Catatonk at Candor, heads at White Church on the divide 9 miles southeast of Ithaca. This divide is traversed by the capacious outlet channel of the glacial Lake Ithaca (30, page 47), with altitude 990 feet. But 2 miles north, at Brookton, is a handsome terraced gravel plain with elevation up to 1040 feet; while northeast of Brookton the valley of Six Mile creek has extensive plains reaching to Slaterville Springs, and up to 1120 feet.

The Slaterville plains were formed in a local glacial lake held in by an ice tongue that covered Brookton and blocked the valley. The first outlet of the Slaterville lake was eastward across the swamp col, at about 1270 feet (see the Dryden sheet), to the west branch of Owego creek. A second and lower outlet was the clean-cut rock channel on the nose of the hill south of Brookton, having an altitude of 1075 feet. The lower Slaterville plains correlate with this later outlet.

There remains the complication in the strong gravel plains out in the open valley at Brookton, with elevation up to 1040 feet, or 50 feet over the White Church divide and outlet channel. The form and relation of the latter do not indicate much down-cutting. The probable explanation is that drift-barrier lake waters followed the receding ice front up the Catatonk and Willseyville valley and into the Cayuga valley, similar to the invasion of the Seneca valley previously described. Benches and terraces and deltas lie on the valley sides over White Church and southward to Owego, but in the constricted valley at Willseyville and below Candor these may represent valley filling and a graded stream instead of lake.

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[1] The accurate contouring of this locality with five-foot interval, and the correct diagnosis of the origin of the deposits with their relation to the topography, and the clear translation of the story of events, would be worth a master's degree to both the topographer and the geologist. The area is commended to the department of geology of Cornell University.

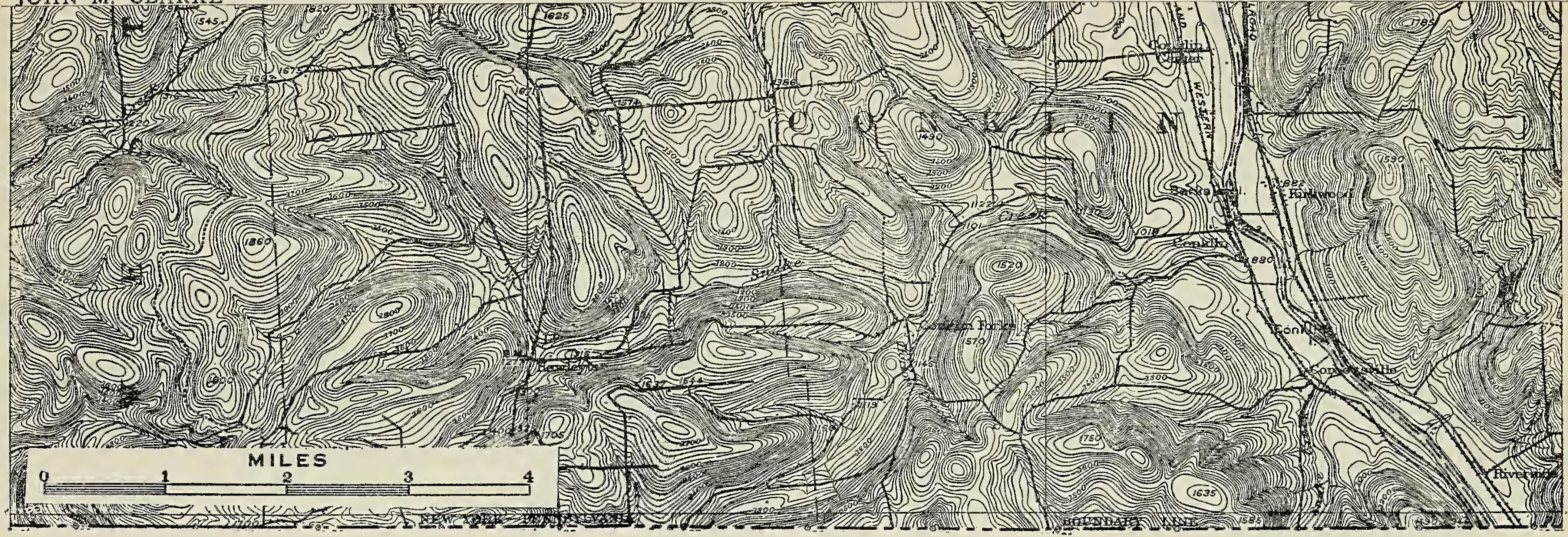
Binghamton District

Binghamton sheet, plate 15

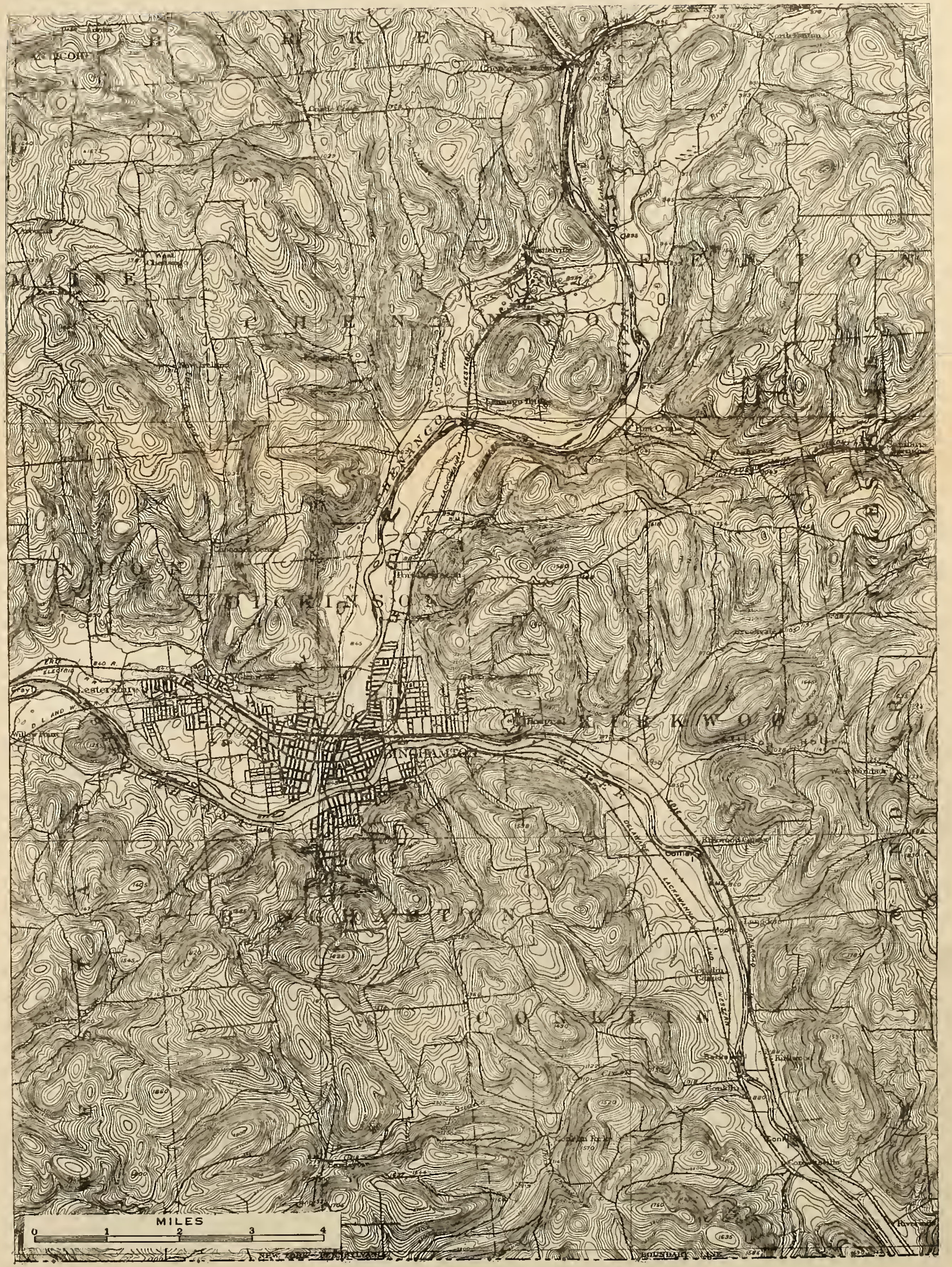
The city of Binghamton is a good example of the influence of physical features on the location and growth of cities. The city stands on inferior lake plains, from 860 to 900 feet elevation, the river falling from 830 to 820 feet. The central and business part of the city is on ground at 860 feet, and fragments of the eroded and excavated gravel plains are conspicuous in the western part of the town, especially south of Main street, at 900 feet. North of the city in the Chenango valley are extensive remnants of plains which once filled the valley. At Hillcrest these are over 900 feet, but over 920 feet in the Kattel loop of the old valley. At the Chenango Valley cemetery the plain rises to the full height of the Binghamton lake, about 950 feet at this point. A mile southeast of Port Dickinson is the delta of Brandywine creek, which shows good delta structure. The factory of the Binghamton Brick Company stands on the southern part of the plain. The subsiding lake and the Chenango river have eroded the delta so as to give a steep west-facing front. The Lackawanna railroad lies below the cliff front, while the Delaware and Hudson railroad has a deep cutting through the delta, exposing the upper and later beds which are coarse, shingly stuff, shown in plate 31. Between the two railroads, on the extension of Blanchard avenue, is the gravel pit of Peter Merrill, which gives an interesting section of sand and gravel beds. The student may find here an excellent record of the events connected with (1) the receding ice front, shown by (2) the gravel from the glacial waters, and succeeded by (3) land stream deposition of coarse stuff, poured into (4) lake waters of falling level, and (5) erosion by the river and creek.

In the eastern part of the city, about half-way to the Binghamton State Hospital, a high-level delta was built by Chamberlain creek. The Fairview School and the Chenango Silk Mill, on Robinson street, stand on the lower plain with altitude of about 900 feet. Passing north up the creek and the unimproved Glen avenue, the delta gravels underlie Bradley, Griffith and Nash streets. The upper limit of the delta appears to be near Monroe street, with height about 945 feet.

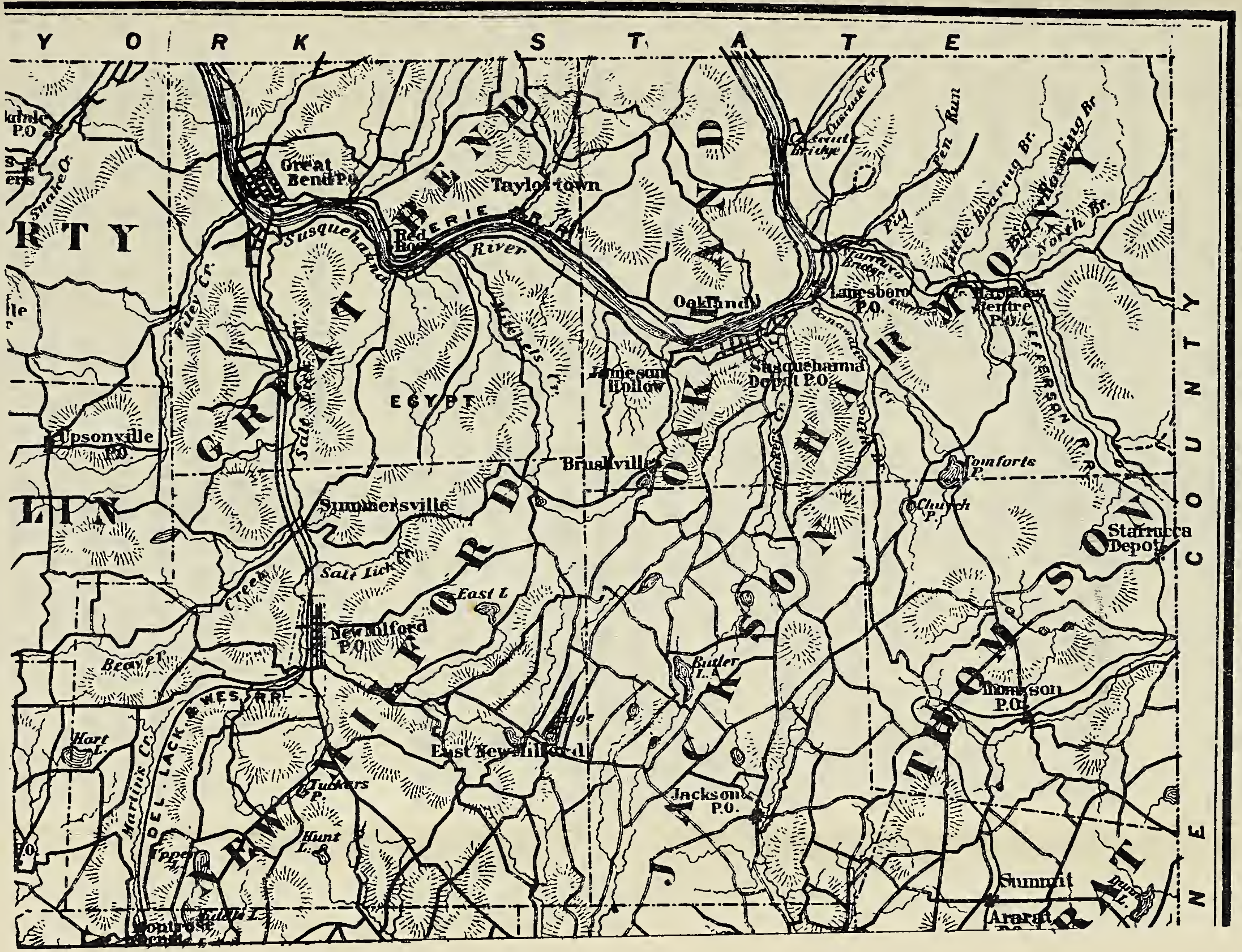
On the south side of the valley the street railway to Ross Park is on a stream delta, the terminus of the line being at the apex of the fan, and above the water level. A mile west of Ross Park is a road corner with map elevation of 888 feet, on the city line. The



Binghamton District



Binghamton District



Great Bend–Lanesboro District

road is on the front of a delta built by a brook from the south, and a farm residence stands nearer the water level. Here, as in many cases, it is difficult to determine the precise lake level on the delta, as the delta shades up stream into the flood plains, and laterally the water deposits shade into the modified land surface. Similar deltas will be found at the mouth of all the streams flowing down from the highland. The difficulty in determining the summit level of the lake gives interest and value to the study.

The Binghamton sheet shows the river and valley features south to the state line, about 3 miles below Great Bend. The evidence of standing waters is abundant along both sides of the valley, in the uniformly bedded and well assorted sand and gravel. The tributary streams have rather poorly developed deltas. A good delta plain occurs at Langdon flag station on the east side of the valley, contributed by two nameless brooks. The eroded front is clearly seen from the highway. The summit of silty sand, is about 925 feet elevation. Lying south of the parallel of Binghamton the locality has been less uplifted. The lake plane at Great Bend is taken as 915 feet. At Binghamton the water plane is about 945 feet.

Professor Brigham (25, page 29) gives well records in the Binghamton district, ranging from 55 feet to rock in the southern part of the city to 160 feet a mile north of the railroad stations. It is probable that the axis of the buried valley lies much north of the river, as the river has been pushed over against the south wall of the valley by the delta of the Chenango. Russell Shear, whom Professor Brigham quotes, informed the writer 219 feet was the depth to rock at Port Dickinson, and 240 feet was the depth to rock at Union. The latter had ground surface at 820 feet, making the altitude of the rock bottom at Union 580 feet.

Great Bend–Lanesboro District

Plate 16

From above Lanesboro to below Great Bend, about 15 miles, the southward curve of the Susquehanna river lies in Pennsylvania. The lack of topographic maps is the more unfortunate as this most interesting stretch of the river valley has the only postglacial rock ravine, the only drift dams which are well preserved, and the largest and finest esker in the entire length of the river.

As this curve in the ancient valley lay athwart the general direction of the ice movement it was favorable to the catchment of glacial drift and was partially filled with moraine. Two miles above Great

Bend village the moraine blockade was complete. The ponded water found escape along the north side across a tongue of rock that projected from the north wall, and has cut a short rock ravine. This was described by I. C. White in his report on Susquehanna county (2) as follows:

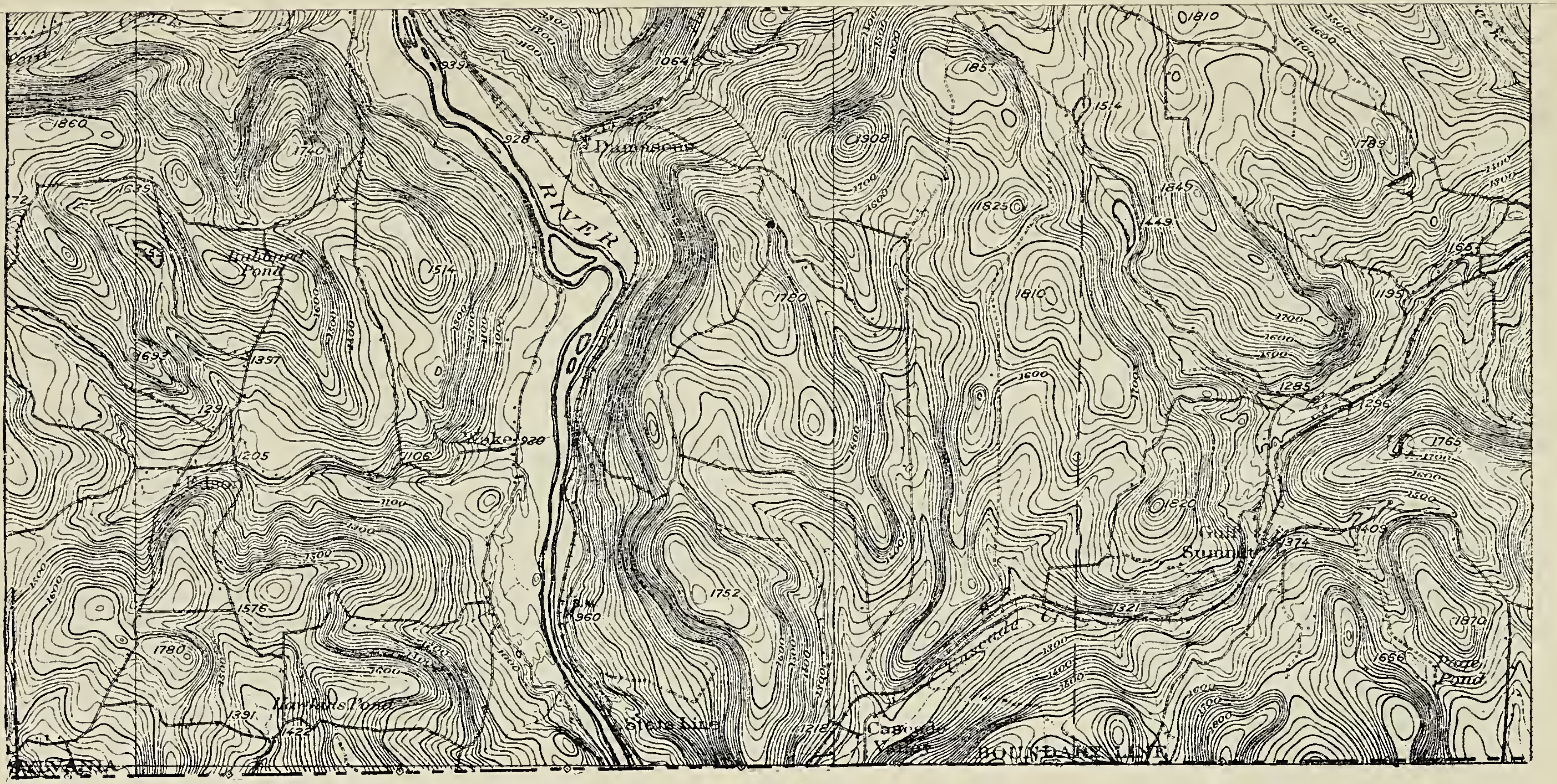
> About 2 miles above Great Bend depot the Susquehanna river flows through a narrow gorge, only 100 yards wide, where it is hemmed in by walls of outcropping strata (page 91).
>
> . . . But this is evidently a new cut, since the ancient channel of the stream may now be seen one-half mile farther south, filled with drift which silted it up during the Glacial Epoch; thus it is possible that in all cases where a rock bottom is now seen in the Susquehanna it is not flowing over the ancient or preglacial channel (page 93).
>
> The appearance of the Susquehanna valley is such as to indicate the presence of an old buried channel of considerable depth (page 93).

The Erie railroad follows the north side of the river all the way from Binghamton to Susquehanna village, and its cutting for the tracks has changed the north wall of the short ravine. The vertical south wall is about 100 feet high, and the width of the river is about 300 feet. The length of the ravine is less than 1000 feet. The highway passes over the ridge above the railroad and gives good views of the features (plate 32).

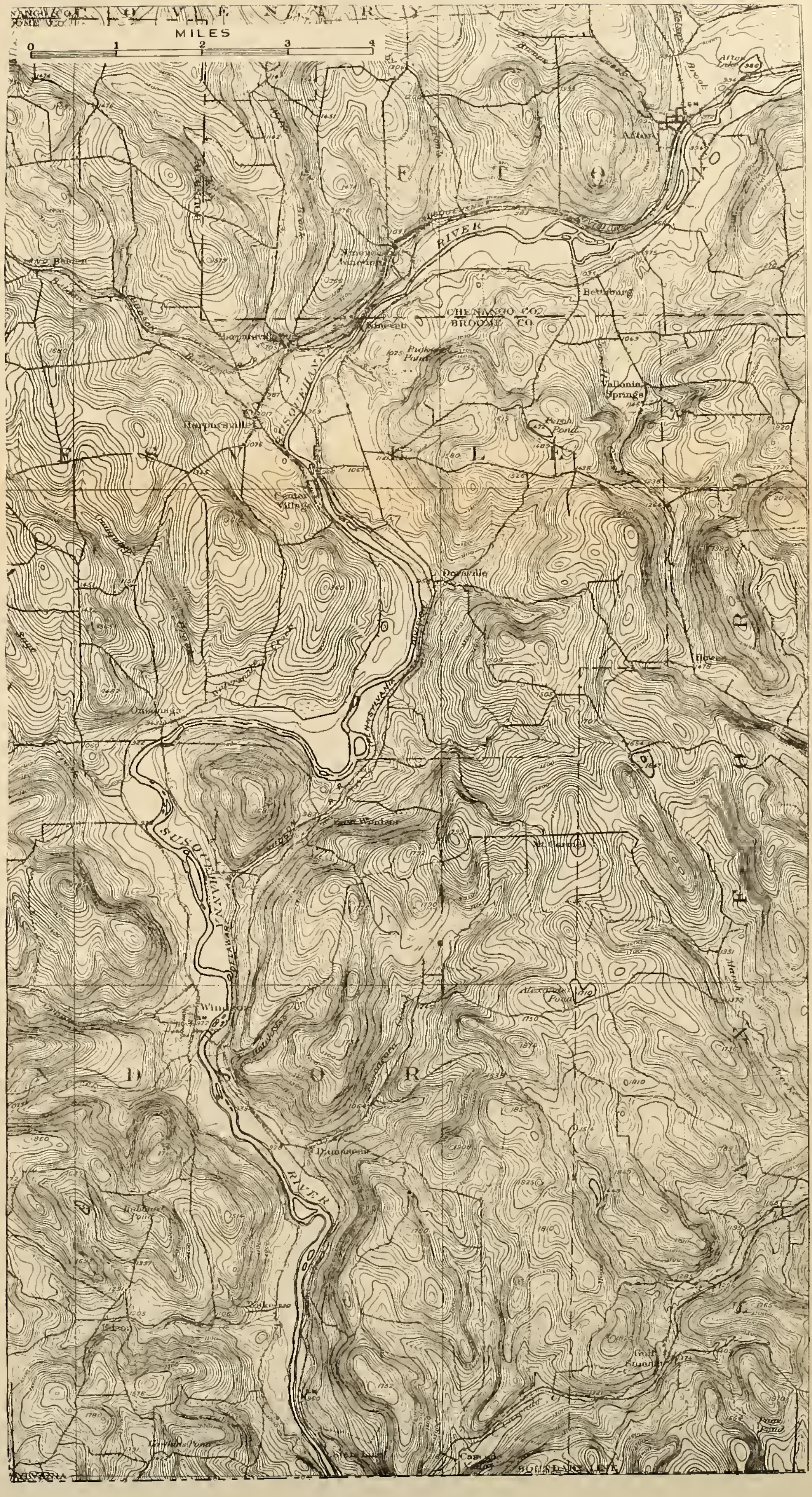
The old valley at the villages of Susquehanna and Oakland is probably the narrowest in the entire valley, and here is another drift dam which held temporarily to high level the waters in the valley above. An early overflow of the morainal lake was over the north side of the barrier, close west of Oakland, where cataract scourways cut by the outflow have elevations of 985 and 990 feet. The trench finally cut by the river is on the south side of the valley. At Susquehanna village the evidence of standing water is found on the valley side to 1010 feet. At Lanesboro the delta built by Canawacta and Starucca creeks gives a terrace at 1004 feet. Since the level of the Binghamton lake at Great Bend is 915 feet it appears that the Oakland moraine dam held up the Windsor-Harpursville water about 100 feet.

The third special feature in this district is the massive Lanesboro esker (plate 33). This is nearly 2 miles long, on the west side of the river but in the middle of the curving valley extending from Susquehanna around to northwest of Lanesboro.

Another attractive object in this locality is the famous Starucca viaduct at Lanesboro, which carries the Erie railroad across the



Windsor–Harpursville District



Windsor–Harpursville District

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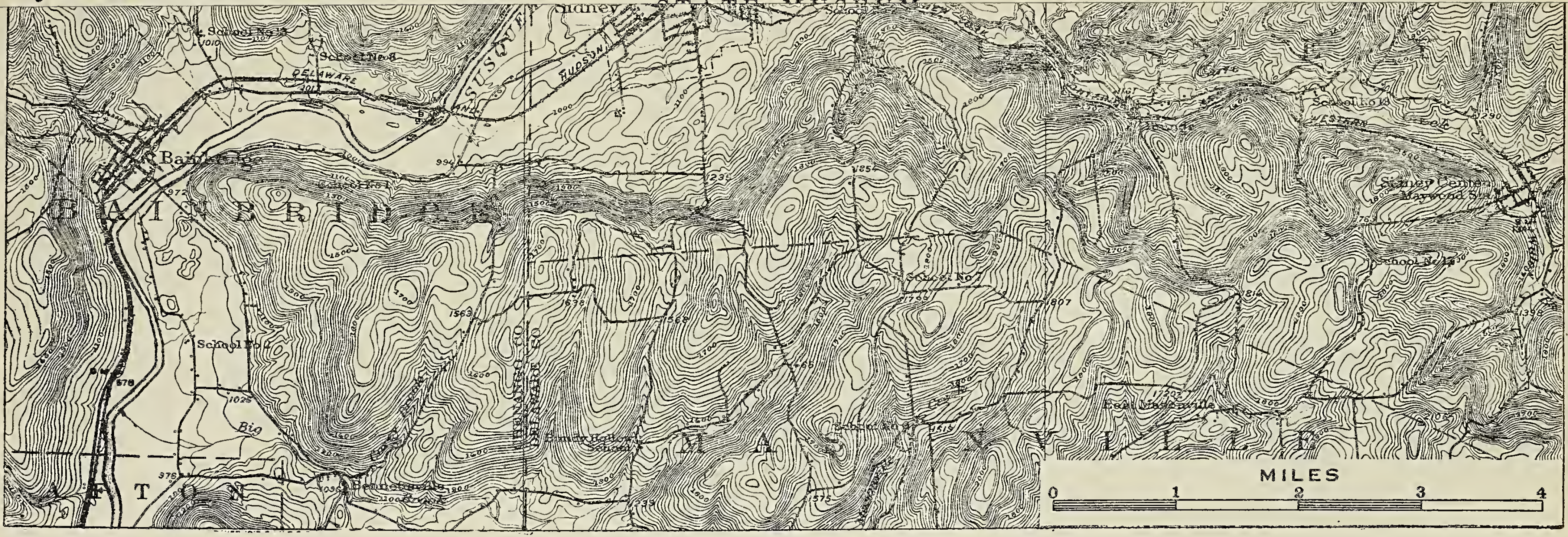

Bainbridge–Sidney–Unadilla District

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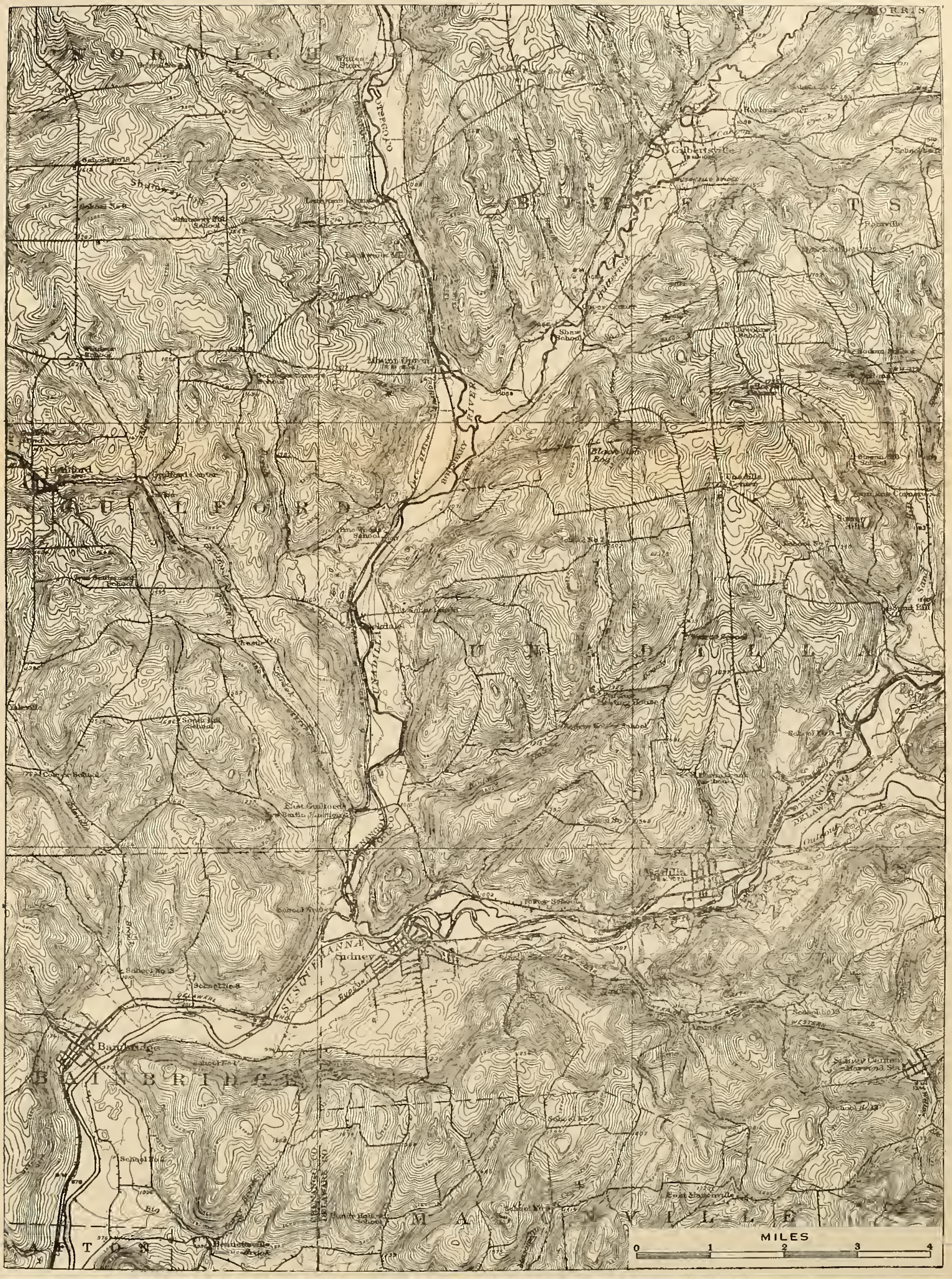


Bainbridge–Sidney–Unadilla District

Starucca valley. It is a massive bridge of cut sandstone, finished in 1849.

The fuller study of the geography and geology of this very interesting district must await the topographic maps. For altitudes at present we must depend on the track elevations of the railroads. These are: for the Lackawanna road, Hallstead 903 feet; for the Erie road, Great Bend 880, Hickory Grove 896, Susquehanna 910, Susquehanna Junction 983; for the Delaware and Hudson road, Lanesboro 956 feet.

Windsor-Harpursville District

Nineveh sheet, plate 17

The district covered by this map extends from the state line to 2 miles above Afton, a distance of 24 miles. In this stretch the river falls about 80 feet, being 960 feet at Afton and 901 feet above the dam at Windsor. The lower plains of the glacial waters are conspicuous and the villages are built on deltas of the tributary streams.

One of the finest displays of plains in the whole length of the river is on the east side of the valley, opposite Harpursville and Nineveh Junction. They are clearly seen from the Delaware and Hudson railroad lines. By leveling from the United States Geological Survey bench at Harpursville Station the highest of the wide terraces is 1075 feet, which is the theoretic elevation as shown by the profile (figure 8).

Bainbridge-Unadilla District

Unadilla sheet, plate 18

This map is of recent survey, with fine expression, and the plains can be recognized on the sheet. Here we find the junction of the Unadilla valley, which in the beginning and closing phases of the glacial flow brought in the waters of the Mohawk valley and the Adirondack highland (plate 8).

The three villages of Bainbridge, Sidney and Unadilla stand on lower plains of the glacial detritus. The fall of the river on this quadrangle is about 55 feet in 17 miles by the valley. The summit plains rise from about 1100 at Bainbridge to 1160 feet on the east edge of the area, near Wells Bridge. The high-water features appear strong the whole length of the valley, but especially so above Unadilla. Here a heavy kame area, with high relief and numerous kettles, has been top-leveled by the standing waters. The terraces do not appear to good advantage from the railroad as this lies too low.

At Sidney the Unadilla added its glacial flood to that of the Susquehanna, and the combined flow did not permit the building of a delta. The theoretic level for the summit plains in this locality is 1125 feet (figure 8), and good plains occur up to 1100 feet. One of these lies a mile northwest of the village, on the east wall of the Unadilla valley. The cemetery southeast of the village is on a gravel plain that rises, by the map contours, to 1100 feet. On West Main Street, which runs due south, the wide and gently sloping plains rise to the south boundary of the village, where the elevation is 1100 feet. Some gravelly and sandy surfaces indicate the presence of water at somewhat higher levels.

The composition of the plain is shown as bedded sand by the road cutting at the junction of Secor street (plate 34).

The topographic sheet gives no precise elevation at Sidney. The Delaware and Hudson railroad at the station has an elevation of 993 feet.

Oneonta District

Oneonta and Delhi sheets, plate 19

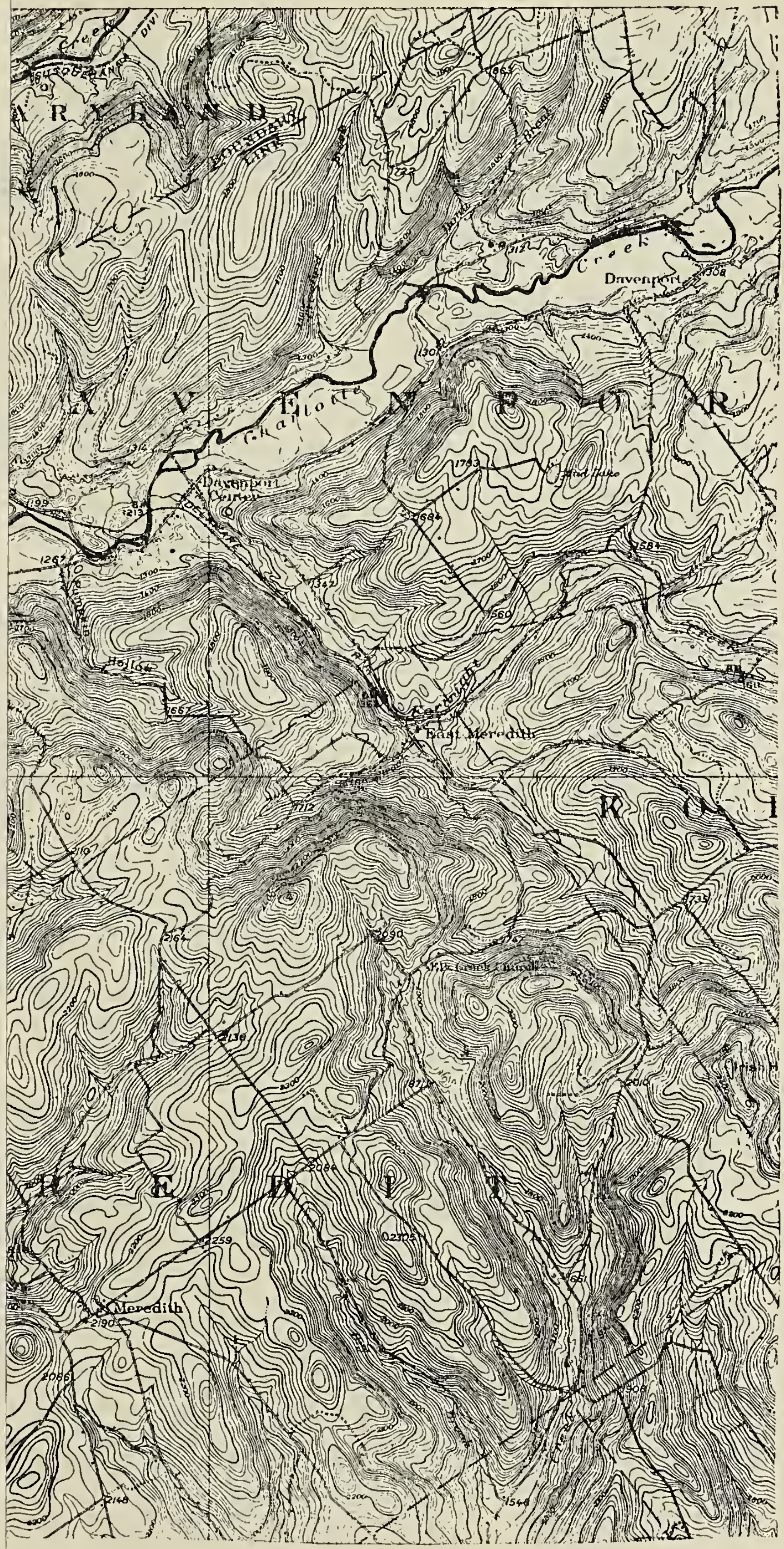
This recent map, like the preceding, exhibits the valley features in excellent expression, but the high plains are not so extensive. East of Oneonta the heavy kame-moraine has been largely removed by river erosion.

In the 19 miles of valley on the two quadrangles the river level rises from about 1025 at Wells Bridge to 1120 feet at Colliersville. The summit water level rises from 1160 to something over 1200 feet east of Oneonta.

The several creeks pouring in from the north built high-level deltas, remnants of which are seen at the mouths of all the valleys.

The city of Oneonta is mostly on a lower plain, at 1120–40 feet. In the eastern part of the city, toward the city line, is a terrace up to 1200 feet. In the northern section Wilbur Park adjoins a handsome plain at 1180 feet. Wilson avenue skirts the edge of the plain, while Walling boulevard, Taft and Roosevelt avenues lie across the plain. Along Chestnut street, in the western extension of the city, is a good terrace; while westward toward Otego creek, is an extensive plain at 1120 feet. Up the Otego valley the lower terraces are conspicuous with fragments at 1100–60 feet. At West Oneonta the summit of Banner creek delta is 1200 feet.

Lines of the standing-water work appear faintly along the valley sides in the Oneonta district, but are likely to be confused with glacial flutings and rock benches. East of the city the river has two important tributaries, Charlotte and Schenevus creeks, which

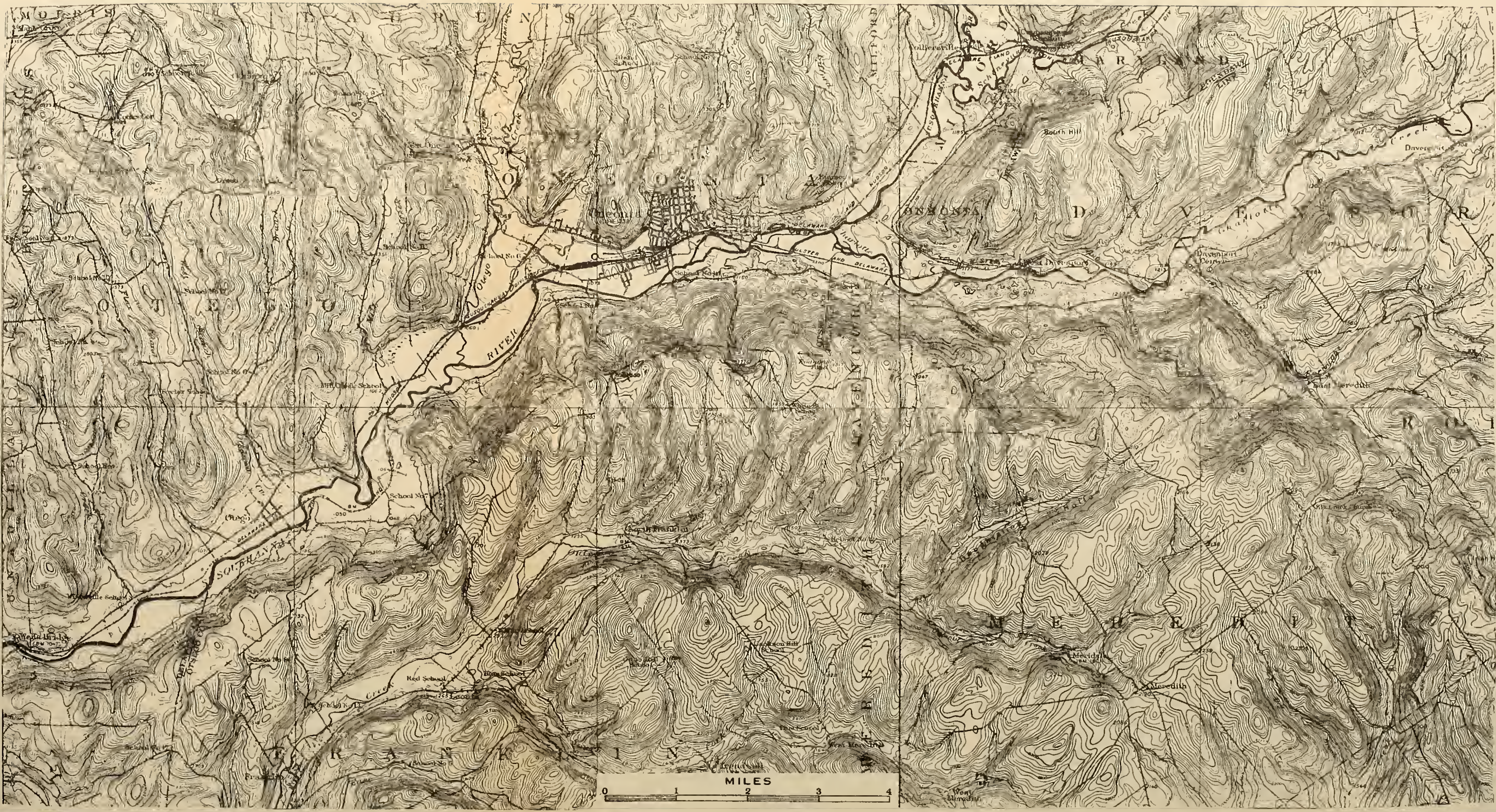

Creek
SUSQUEHANNA
DIV
A R Y L A N D
BOUNDARY LINE
Creek
Davenport
Charlotte
D A V E N P O R
Davenport Centre
Mud Lake
Hollow
East Meredith
R O
Elk Creek Church
M E R E D I T H
Meredith

JOHN M. CLARKE
STATE GEOLOGIST

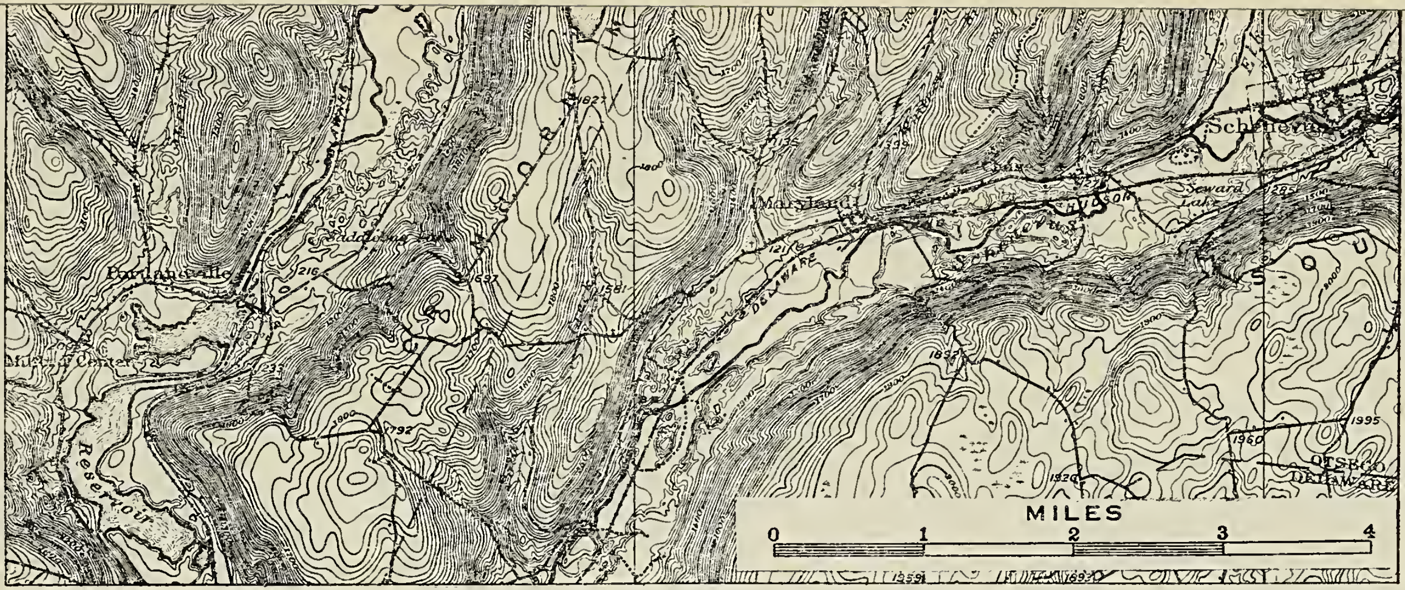
UNIVERSITY OF THE STATE OF NEW YORK

STATE MUSEUM

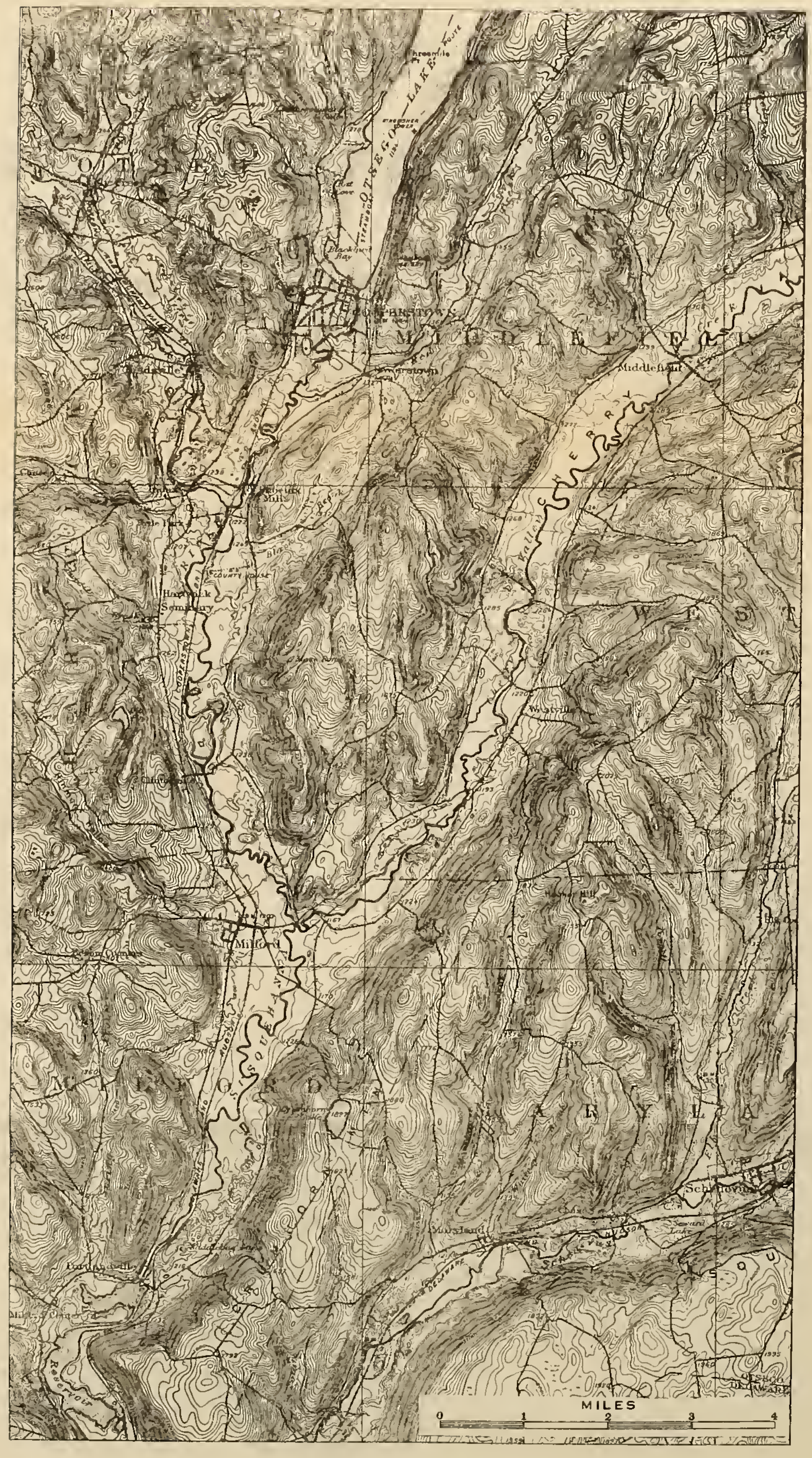
BULLETIN 256 PLATE 19



Oneonta District



Cooperstown District



Cooperstown District

supplied the main valley with much detritus. The small area covered by the Delhi sheet holds much of interest for detailed study. Indeed the entire district is excellent for the study of glacial and stream phenomena, and is commended to the students of the Oneonta State Normal School.

Cooperstown District

Cooperstown sheet, plate 20

This map also has good detail and the reader can recognize the glacial features. Kame areas with numerous kettles are prominent deposits above Portlandville, also at Index and in the tributary valleys of Schenevus, Cherry and Oak creeks.

The river level rises from about 1150 in the Portlandville reservoir, judging from the map contours, to 1194 in Otsego lake, the distance being 13 miles by the valley, but nearly twice that by the river meanders.

Excellent remnants of the high plains occur in the Portlandville district, where the kettles indicate morainal deposits and a possible blockade of the valley. A good display is found at Milford, and especially from Hartwick Seminary to Cooperstown. The valley of Oaks creek, from Index north to Schuyler lake holds a great volume of kame and lake detritus, with huge kettles above Fly creek. A particularly fine example of leveled kames with numerous large kettles, a so-called "pitted plain," is seen at Index (plate 35). Some of the funnels or inverted cones are 30 to 50 feet deep.

The village of Cooperstown is mostly on a higher plain which in the western part of the town is 1260 feet. Kettles occur in the village, and it is probable that the material of the plains is glacial, or kame-moraine, and has been leveled by lake waters.

Otsego lake is said to be 180 feet in depth. Borings behind the building of the A. H. Crist Company, on Main street, went 160 feet to rock (letter from C. F. White). These data make the elevation of the lake bottom 1014 feet, and rock under the village 1070 feet. It is evident that Otsego lake, like nearly all the lakes of the glaciated territory, is due to the drift blockade of an old valley, or is a drift-barrier lake.

At the head of Otsego lake (plate 21) the standing water evidence is clear in the silt and sand plains. The elevation of the lake is given as 1194 feet. Near Springfield Center the sand plains are over 1260 feet. The wide plains above Hyde Bay, toward East Springfield, reach 1270 feet. Here we find the extreme northern reach of the Susquehanna lake waters in the main valley. The profile of these northern plains is given in figure 8.

SPRINGFIELD GLACIAL CHANNELS

Richfield Springs and Canajoharie sheets, plate 21

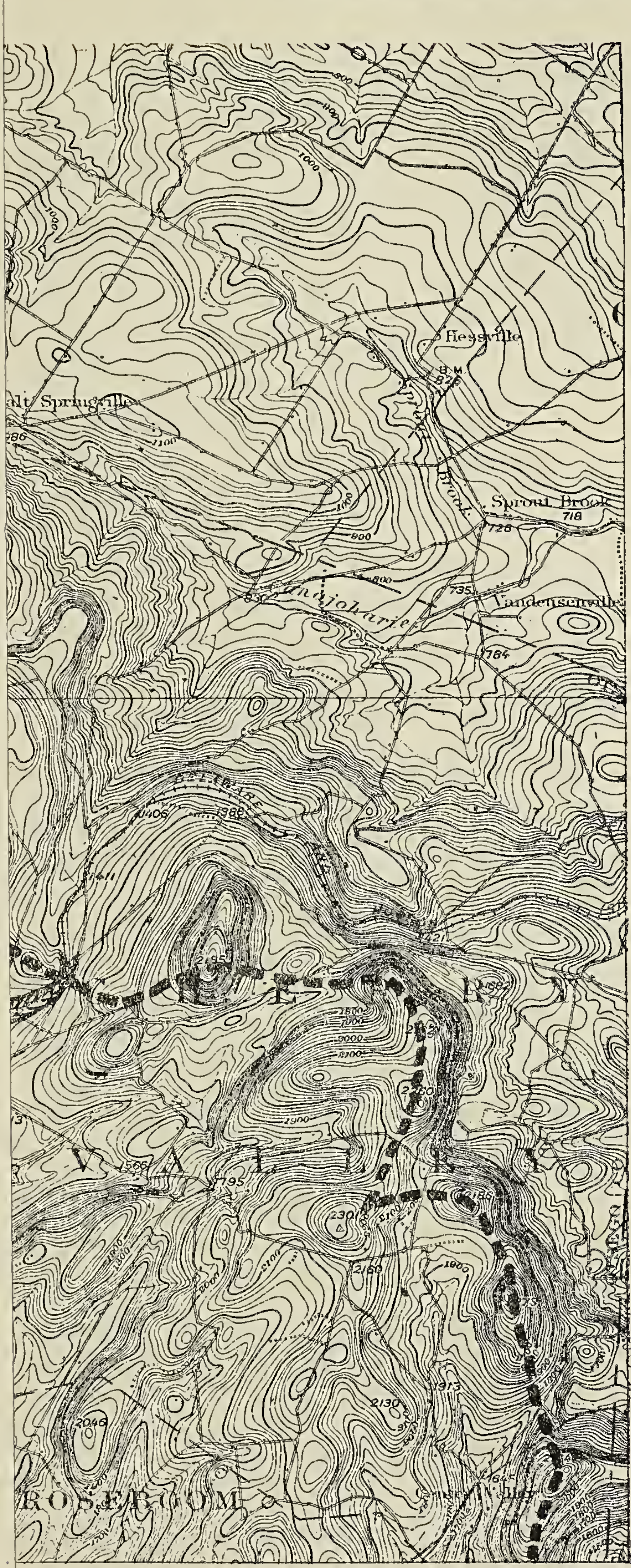
The singular and unique features in the Otsego lake region are two channels carved by glacial waters, with torrential flow, south of the Mohawk divide. These two channels have singular relation to the topography and to the drainage history. The locality had brief mention in a former paper (34, pages 19-24).

Six miles northeast of Otsego lake are two cols on the divide which separates the waters of the Susquehanna from those of the Mohawk. Another col is a mile above Cherry Valley, at the head of Cherry Valley creek. The three cols are indicated in plate 21. Their elevations are as follows: Summit lake 4 miles above Springfield Center, 1360 feet; East Springfield, 1 mile north, 1420 feet; Cherry Valley, 1 mile north, 1410 feet.

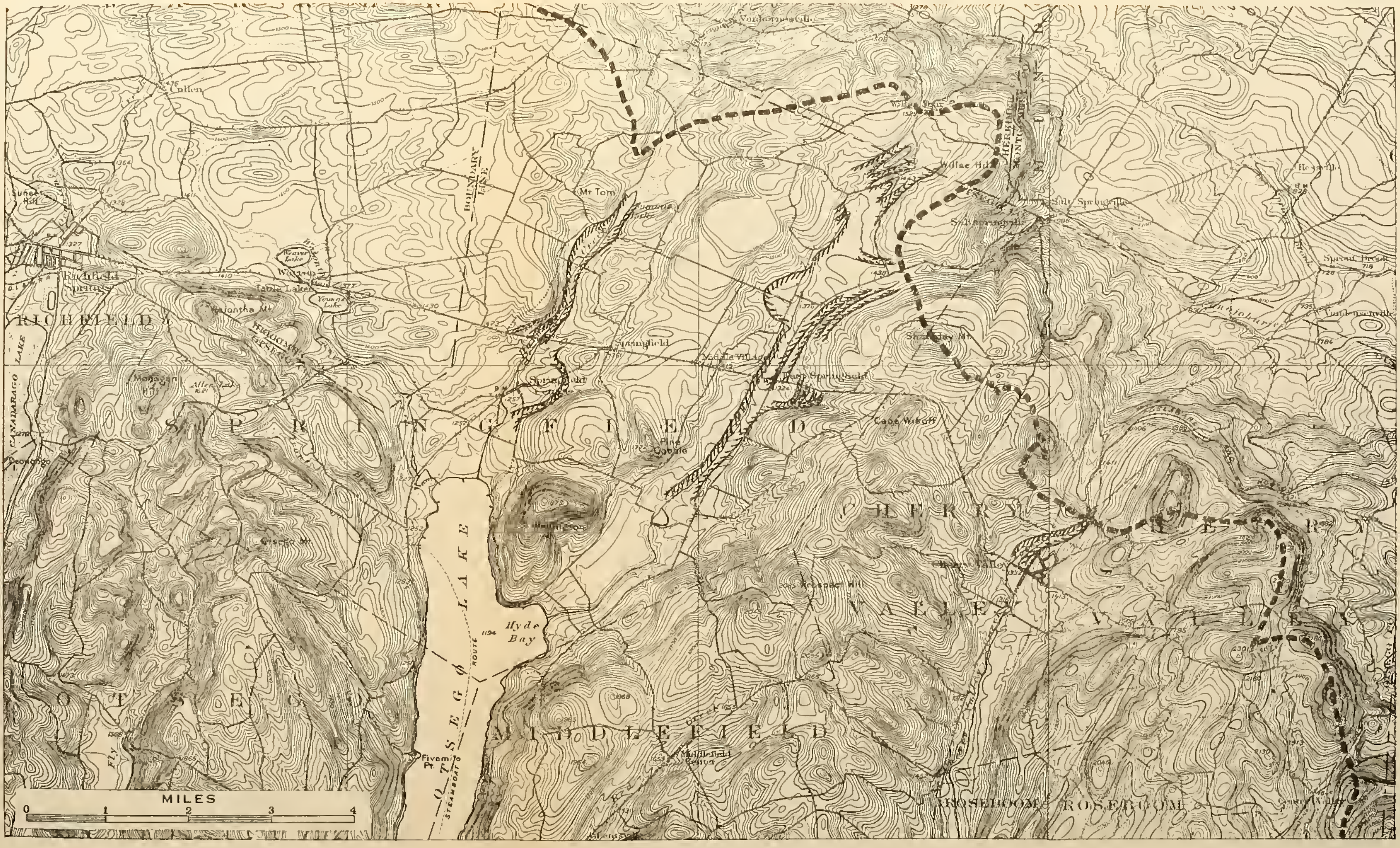
The pass at Cherry Valley has been normally cut and shaped by stream flow. It is a typical small channel across a divide. It did not carry a heavy flow, nor for a long time; but waters from the Mohawk side passed across to Cherry Valley creek in time and volume sufficient to produce distinct channel form (plate 39).

The two Springfield cols have not been cut distinctly by flow of water across them, but the remarkable condition is found of heavy, torrential flow and rock erosion immediately below the water-parting line. The channels are shown in the map (plate 21). A mile west of Willse hill, and 3 miles north-by-east from East Springfield other sharp channels are found, but a mile south of the divide and beneath it in altitude.

When we observe that the Cherry Valley channel is only 10 feet lower than the East Springfield notch and 50 feet higher than the Summit lake col, it is apparent that there must have been some interference with the free flow of Mohawk waters across the divide. This is further emphasized by the existence 15 miles west of the Summit lake col of a capacious river channel across the divide at Cedarville, with elevation of 1220 feet, or 140 feet lower than the uncut Summit lake notch. The explanation is found in the physical conditions of the waning glacier in the Mohawk valley during its latest phase, and the relation of the ice body to the land topography. This relation of the ice lobes is shown in plates 7 and 8. In the reduction of the Quebec glacier a stage was reached when only a neck or strait of ice lay over the Mohawk valley (plate 7). The Adirondack highland was then partially bare and the precipitation on the



south of the divide



SPRINGFIELD DISTRICT; HEAD OF THE SUSQUEHANNA RIVER

The broken line marks the divide between Mohawk and Susquehanna drainage. Channels of glacial rivers are shown south of the divide

exposed area and the water from the melting of the enclosing ice had no possible escape except across the Mohawk ice strait. Such outflow must have been at the lowest or weakest section of the ice strait, which was probably where the westward flow up the valley from the Hudson ice lobe met the eastward push of the Ontario ice lobe. At this locus of head-on collision the ice eventually became stagnant and melted, giving place to a lake between the opposing ice tongues (plate 8). The locality of weakness and lower elevation in the surface of the ice strait appears to have been opposite the headwaters of the Susquehanna river. While the south edge of the ice strait still covered and protected the cols, and the land divide, the waters from the Adirondack area poured across the neck of ice, fell on the land with torrential force and passed down the valleys to the Susquehanna river. The East Springfield channel especially shows the effects of torrent flow on limestone rock.

When the former paper (34) was written the East Springfield channel had not been seen. Here the limestone channel shows fluting along the east side, possibly partly due to ice abrasion but later to stream flow along the east margin of the tongue of ice that passed across the col and pushed some distance down the valley. Plate 37 shows some of the erosion forms. There are interesting details here which maps and photographs do not readily exhibit. The erosion phenomena here are not confined to the middle of the valley but appear on the east side, with evidence of the shifting and spasmodic flow which naturally accompanies a changing ice margin. They also indicate a volume of flow much greater than could be supplied from the melting of the valley ice lobe. The evidences of lateral drainage appear up to about 100 feet above the East Springfield corners, the latter being 1328 feet above tide. The sharp channels cut in rock by the lateral streams are seen east of the village, on the south side of the road. The high benches on the east side of the valley are seen extending northeast of the village for more than 2 miles. Some of these features are shown in plates 37 and 38.

Some of the higher, bare-rock ledges may be partially shaped by ice erosion, as mentioned above, for the valley surfaces in general exhibit a smoothing or drumlinizing effect, and a tendency to horizontal lines. Plate 22 shows numerous west-pointing drumlins which were built by the earlier and stronger westward push of the Hudson-Mohawk lobe.

The detritus carried by the two Springfield rivers was swept into the Cooperstown lake and was spread out to form the wide plains at the head of Otsego lake, and especially above Hyde bay, with elevation of more than 1260 feet.

The Cherry Valley channel represents free flow across the divide from a lake on the Mohawk side, the ice margin being removed from the land at that point. The short channel on the col and the weak channel features at and below the village rule out any large and long-life stream. This suggests that the Cedarville channel, 21 miles west and 190 feet lower, drew the water from this district. It also appears that the Cedarville pass became effective, by the waning of the Ontario ice lobe, before the Springfield cols were relieved of the ice cover, for otherwise those notches in the divide would have been cut by outflow, like the Cherry Valley pass. It is possible that the Cedarville pass might have had an experience similar to that of the Springfield cols, but if so the later and very heavy river flow has destroyed the glacial features. Plate 8 shows the supposed relations of the ice, lake and river during the Cedarville outlet stage.

It should be borne in mind that during the time of the removal of the glacier from this district the land there was some 300 feet lower than it is today.

COLS ON THE SUSQUEHANNA-MOHAWK DIVIDE

Winfield, Sangerfield, Morrisville sheets, plate 22

In regard to the glacial waters, the two Springfield cols and the Cedarville and Cherry Valley passes represent two distinct types of channels. West of these are several passes which carried glacial water but of a type quite unlike either the Springfield or the Cherry Valley.

For comparison of the passes which carried overflow of the glacial waters from the Mohawk valley to the Susquehanna drainage system, all the cols are listed below, pas[illegible] from east to west.

1 Cherry Valley, 1410 feet; head of Cherry Valley creek

2 East Springfield, 1420 feet; head of Shadow brook, to Otsego lake

3 Summit lake (Springfield Center), 1360 feet; head of Hayden brook, to Otsego lake

4 Cedarville-Chepatchet, 1220 feet; head of Unadilla river

5 Cassville (Richfield Junction), 1260 feet; head of west branch of Unadilla

6 Sangerfield (Waterville), 1250 feet; head of Sangerfield river, to Chenango river

7 Bouckville, 1160 feet; one head of Chenango river

8 Whites Corners (Morrisville Station), 1180 feet; one head of Chenango river

9 Peterboro (Morrisville), 1300 feet; main head of Chenango river

Of these nine passes across the divide between the Mohawk and Susquehanna waters the only ones which carried a free stream from open lake on the Mohawk side are the small Cherry valley and the capacious Cedarville. The latter was the outlet of the early high-level Mohawk water, the Herkimer glacial lake, shown in plate 8. Referring to the list above, however, it is seen that two other passes, numbers 7 and 8, at the two proper heads of the Chenango valley, are much lower than the Cedarville channel. The explanation would seem to be that these two low cols were blocked by the Ontario ice lobe during the life of Lake Herkimer. They lay so far west that they were shut off from the open lake by the ice front which pressed against the high ground between Cedarville and Bouckville, until the weakening of the Hudson ice lobe on the Helderberg scarp, southwest of Albany, permitted eastward escape for the Mohawk valley waters (34, plate 14).

All the passes west of the Cedarville, however, except the Peterboro, were flooded by glacial outflow, and constitute the peculiar third class of water passes. The two river systems of which they were heads, the Unadilla and Chenango, had a glacial history similar to that of the Susquehanna, and their valleys appear to have been also flooded to the heads, at the ice front. Since the region was 300 feet lower than it is today, the valley gradients were less. A series of morainal lakes probably carried standing water over the cols to the ice front. Today the line of water parting at the four lower cols (5-8) lies on wide detrital plains, abutting on the north against heavy kame-moraines. These hold numerous kettles, and they were certainly built at the stagnant ice margin by glacial outwash into relatively quiet water. The preglacial divides at these passes are probably buried beneath the detrital plains, and may lie some distance south of the present line of water parting.

The characters of these passes and the valleys leading south indicate a flow of water more copious than would be supplied by the melting of merely the local ice margin, and they give a strong suggestion of outflow from the melting ice sheet over Canada and the Adirondacks even greater than by the Springfield channels (see page 79).

NORTHERN TRIBUTARY VALLEYS

Valleys Eastward

Passing eastward from the Susquehanna northern tributary valleys are Cherry Creek, Schenevus, Charlotte, and some small streams on the south. They have been partially described in the preceding pages and the topographic sheets have been named which map the lower portions of the valleys. The Richmondville and Hobart sheets complete the territory.

These valleys all carried glacial waters with heavy detritus. The floods were graded to the high waters in the main valley as base-level, in consequence of which these tributary valleys hold their plains at higher elevations. To map the plains and determine their elevations and gradients, with their relation to the waters in the main valley would be excellent work for the geography classes in the high schools.

Unadilla Valley

Unadilla, New Berlin, Sangerfield, Winfield sheets

In size, form and stream phenomena the Unadilla valley is equal to the Susquehanna above the junction of the valleys at Sidney. The writer has not examined the valley, but the topographic sheets are recent and show the features clearly.

During the life of Lake Herkimer the Unadilla valley carried a glacial flood larger than did the Susquehanna above Sidney. The upper plains, above Unadilla Forks, are very extensive. The descriptions of the other large valleys apply in theory to this valley.

Chenango Valley

Morrisville, Sangerfield, Norwich, New Berlin, Oxford, Greene and Binghamton sheets

The massive detrital deposits in the great valleys of the glaciated territory were formerly regarded as wholly the work of enormously flooded rivers, and in the nature of flood plains and "valley train" drift. We now know that for the low valleys, like the Hudson, Connecticut, and many deep valleys of New England, and the St Lawrence valley, the plains are deposits laid in the sea or in sea level waters, representing marine submergence, previous to the land uplift. In higher valleys, like the Susquehanna and its tributaries, the plains are partly, and in some long stretches wholly, the effects of morainal or drift-barrier lakes.

For the Chenango valley the truth was recognized by Professor Brigham many years ago (25). In 1897 he showed that the valley deposits were largely the work of standing water. He also recognized the effect of the lower attitude of the land. Some quotations are pertinent.

> These beds, with the pronounced frontal slopes and lobes, at Bouckville, appear to prove the existence of a water body into which the material was discharged, at least during the later stages of construction. The lake may have been marginal to a shrinking ice tongue merely, or may have been more extended, filling the valley and prolonged southward. (page 24)
>
> . . . Especially, as we have seen, must we lay aside exaggerated notions of floods coursing with great depth and power and strewing materials throughout the valley. (page 27)

An examination of the valley suggests that moraines probably blocked the valley at some points, perhaps at Plasterville, above and below Oxford, at Greene, and possibly at Chenango Forks. The drift obstructions held the waters as lakes long enough for tributary creeks to build high level deltas in the slack waters.

The distance from Binghamton to Bouckville, at the divide, is 69 miles; and the gravel plains rise in that distance from 940 feet to 1160 feet. The differential land uplift between the two points is 135 feet (figure 2). Deducting this from the present rise, 220 feet, leaves 85 feet for the original slope of the waters, or a total gradient of a little more than 1 foot a mile. This small difference in total level was doubtless taken up in the rapids at the localities of drift blockade.

From the heads of the valley (plate 22) a shallow lake appears to have extended south through the Sherburne valley to Plasterville. Between North Norwich (Galena) and Sherburne Four Corners the kame-moraine was leveled by the waters. In the Sangerfield valley a moraine between Poolville and East Hamilton appears to have held a shallow lake from Hubbardville to Sangerfield, as shown in plate 22. In the Norwich district a lake was probably held by drift blockade in the stretch at Oxford; while another lake may have been held above Greene. There may have been a barrier at Chenango Forks of coarse gravel swept in by the glacial Tioughnioga. Below Chenango Forks the waters were probably confluent with the Elmira and Binghamton lakes.

Speaking of the Binghamton district Brigham says:

> That lake waters occupied the valley in whole or in successive sections, for a long time, is clear. The deeper wells all give in general section beds of gravel of limited thickness, a few to 50 feet underlain by almost massive clays from 120 to 165 feet. . . . It is believed that differential northward depression has in any case been an important factor in the history of these accumulations. (pages 29, 30.)

For fuller description of the Chenango valley the reader should consult Professor Brigham's paper (25), which is accompanied with a map of the glacial features.

Otselic Valley

Morrisville, Norwich, Pitcher and Greene sheets

The name of the Otselic valley is less familiar because the valley is not followed by any line of railway and does not hold any large villages. It is a capacious valley, however, similar to those already described, and it carried heavy glacial drainage. It heads in several branches in the high ground of northwest Chenango and southwest Madison counties, and makes junction with the Tioughnioga at Whitney Point, below which point the combined stream carries the latter name. In preglacial time, however, the Otselic was the main stream, the Tioughnioga having been developed by glacial flow.

Very handsome terraced plains lie at the junction of the two streams, above Whitney Point, also above Upper Lisle. Standing water probably reached to Cincinnatus. The glacial features of the valley are similar to those of the other south-leading valleys of the region. The geography pupils in the Whitney Point High School might study and map the plains between that village and Lisle, and then compare the two valleys northward, and explain the difference in size and character.

Tioughnioga Valley

Cortland, Harford, Greene and Binghamton sheets

The Tioughnioga valley is the best example of forced glacial drainage, with production of new channels, in central New York. The valley heads at Cortland and ends at Chenango Forks. It was developed by tying two small valleys which happened to lie in course with the lower stretch of the Otselic valley. The rock gorge 6 miles southeast of Cortland locates the preglacial divide between the heads of the now connected valleys.

The 4 miles of the present valley above the junction with the Chenango at Chenango Forks is another postglacial channel. The former course of the Otselic is evidently the partly filled valley leading southeast from Itaska (Barker), and which meets the Chenango valley 2 miles above Chenango Forks. Plate 5 shows the preglacial stream relations.

The Chenango valley was so effectively blocked by drift at the Forks that the combined flow of the present rivers has been driven against the west wall of the old Chenango valley, very unlike the normal position of the Chenango and Susquehanna junction in Binghamton.

No slack water deposits are found in the Tioughnioga valley above Lisle, as it was occupied by a vigorous stream.

In the east-leading valley which joins the Tioughnioga at Lisle are some very interesting glacial features. From East Richford to Center Lisle, a distance of 5 miles, the valley is occupied for most of the distance by a large esker, which carried the highway some 3 miles. The subglacial stream which made the esker debouched into a lake at Center Lisle, the plains of which are conspicuous between Center Lisle and Manningville. The geography students here might measure the heights of the lake terraces, and find the controlling outlets of the lake.

Cohocton Valley

Wayland, Naples, Bath, Hammondsport and Corning sheets, plates 23 and 24

This large and important valley is perhaps the finest in the State as an exhibit of glacial river drift, or "valley-train." Fortunately it is not only mapped, but is followed its entire length by two trunk-line railroads, the Erie and Lackawanna, so that it is easily available for car-window observation. Extensive high-level terraces and benches are constant features, on which are located the villages, Painted Post, Campbell, Savona, Bath, Kanona, Avoca, Wallace and Cohocton.

As indicated in plates 4 and 5 the valley was probably produced by uniting several tributaries of the primitive southwest-leading valleys, and the forced union of two such subsequent streams by the glacial flow. It appears certain that the present size and directness from Cohocton down is due to the glacial flood which it carried, during both the advance and recession of the ice sheet. Plate 5 shows the supposed relation of the preglacial drainage.

The Elmira lake reached up the Chemung valley to Painted Post (plate 23), where the Cohocton and Canisteo rivers unite. Above here the wide plains appear to be the high flood plains of the aggraded glacial river. The profile (figure 10) shows the uniform but steep gradient of the plains. Only a minor part of the present slope is due to land uplift, leaving a high gradient for the glacial river.

Many local features should be closely studied; for example, the high gravel deposits and strong lateral channels on the west side of the valley at Cohocton.

Canisteo Valley

Corning, Bath and Hornell sheets, plate 25

Not all of this particularly interesting valley is surveyed. The lower 10 miles, above its junction with the Cohocton, appears on the Corning sheet. The constricted portion, which in preglacial time was probably a drainage divide, is partly shown on the Bath sheet; and the most interesting portion of the valley, from Adrian past Hornell to the head of the valley near Canaseraga, appears on the Hornell sheet.

In origin and direction this valley is similar to the Cohocton; but in form it is unlike the latter. A long stretch of narrow valley from Canisteo down to Addison, a distance of about 25 miles, must have been in preglacial time the paths of two small divergent streams, as indicated in plate 5. In glacial time the valley carried for a long episode the overflow of the Genesee river drainage area (32, plates 11 and 12), which is responsible for the present deep channel. The wide stretch from Canisteo northward, past Hornell and Arkport, was before the ice age the head portion of the broad Dansville valley, and a branch of the Genesee.

The wide portion of the valley holds a variety of unusually good glacial features, which deserve close study and detailed description. The ice tongue which was the last occupant of the valley was the cause of stream erosion along the valley sides, giving horizontal lines, and of local pondings. One of the ice-border lakes has left a delta at the Burden school, 4 miles north of Hornell, the summit outlet being behind the high hill on the South. Other high terraces appear above Arkport and west of Burns. The upper Canaseraga Valley was blocked by the ice lobe, producing handsome lake features in the district of Canaseraga village, which should have special study. A remarkable pitted plain lies east of the village on the brink of "Poags Hole," the creek gorge; and here is the great delta of the Canaseraga creek built in the Dansville lake. These features are partly on the Canaseraga sheet. The wasteweir of the Genesee glacial outflow was the present wide, flat col more than a mile north of Burns, where the effects of river flow over a gravel bottom are clearly shown.

SOUTHERN TRIBUTARY VALLEYS

The small streams tributary to the river from the south and lying east of Waverly have been mentioned. The heavier southern drainage is west of Waverly. The largest stream is the Tioga river, which meets the Cohocton at Painted Post to form the Chemung river. The Tioga, with its western branch, the Cowanesque, drains a large area in Pennsylvania. Other smaller streams flowing directly north are the Seely creek, joining the river south of Elmira, and the Bentley creek, coming in at Wellsburg.

The difference in the glacial history between the north and the south tributaries has been described, page 69.

We have few topographic maps of the Pennsylvania area, and no study has been made of these southern tributaries. Judging from the state map the higher waters in the Tioga system might have been forced by the ice sheet into Pine creek and have helped to swell the flood in the West branch of the river. The lower lakes of the Tioga, like the waters of Seely and Bentley creeks may have passed into Sugar creek, to join the north branch near Towanda.

SUMMARY

Told in the current terminology of stream evolution, the physiographic history of the Susquehanna river is a tragic story. The old river has experienced many vicissitudes. It has suffered the fateful effects of rock control and of robbery by rival streams. It was beheaded, dissected and diverted by pirate streams, and in Tertiary time was partly reversed in its direction of flow. In later time it was blocked, reversed and finally entirely extinguished in New York by the resistless continental Quebec glacier. The final withdrawal of the ice sheet has permitted the renewal of the river, but with altered and subdued character.

This dramatic history, covering tens of millions of years, involves complex geologic factors: the erosion and lowering of the land surface, the diverting effect on the primitive (consequent) drainage by the varying character of the rock strata, changes in the altitude and slope of the land, climatic variations, and the revolutionary effect of glaciation. It is not possible to apportion the relative influence of the several factors, nor to discern the details in the long process of the evolution of the present Susquehanna river system. Nevertheless, a few of the culminating phases are recorded in the existing topography and the geologic deposits, and a brief epitome of the long history is here attempted.

The primitive Susquehanna, with neighboring streams of central New York, came into existence when the area was irregularly lifted out of the interior (epicontinental) sea. This occurred in later Devonian and early Mississippian (Subcarboniferous) time. When the river had its birth, and during its earlier life, there was no Mohawk valley or Ontario basin, as these depressions were subsequently carved out of the Devonian and subjacent strata. The early rivers had their sources in the Adirondack area, or even farther north in Canada, and flowed southwestward into the receding sea, or interior gulf of the ocean, which then lay over Pennsylvania. The extended course in Pennsylvania of what is now the headwaters stretch in New York was in the line of the present Tunkhannock valley, which is crossed at Nicholson by the great new viaduct of the Lackawanna railroad (plate 27). That course is shown in the map, plate 4.

During the immensely long eras of the Mesozoic and Cenozoic (Tertiary) the Mohawk valley and the wide Ontario valley were excavated in the thick and weak Ordovician and Silurian shales. The upper courses of the primitive Susquehanna and its companions, in the Adirondack region, were cut off or "captured" by the creation of the new "subsequent" Mohawk valley and its producing streams.

In manner similar to the diversion of the Adirondack portion of the river, the New York stretch of the beheaded river was diverted westward by the development of west-flowing "subsequent" tributaries in the Chemung shales along the south border of the State, producing the valley from Lanesboro to Waverly. We apply the name Susquehanna to the diverting or capturing "pirate" stream: the beheaded Susquehanna being the present Tunkhannock creek.

By the union of east and west tributaries of the original south-flowing streams in northwest New York a great master stream was developed along the axis of the Ontario basin, which we may call the Ontarian river. That great river probably had westward flow into the oceanic waters in the Mississippi embayment. With the great depth and width of its valley it drew to itself, on the south valley wall, the drainage of western New York, and caused the reversed (obsequent) north-flowing streams of the Finger lakes valleys, and of the Genesee river. It is almost certain that the Ontarian river also reached out through the Seneca valley and captured the Susquehanna. Then the drainage of all central and western New York flowed north and passed out by the Ontarian river to the Mississippi. The Tunkhannock and its companions on the west, Meshoppen and Wyalusing creeks, and the Lackawanna on the east, were the only representatives of the original southward flow. This phase of the preglacial drainage is shown in plate 5.

That adjusted and mature drainage of later Tertiary time was doomed to entire obliteration. With the creation of an ice field in eastern Canada, and its extension and southward invasion as the Quebec glacier, the Ontario valley became filled with the ice body, and the Ontarian river was extinguished. Its north-flowing tributaries were dammed and also finally extinguished, and all the territory of the north branch of the Susquehanna, except a few miles below Berwick, was buried beneath the ice sheet for scores of thousands of years.

Eventually the climatic factors which had produced the slightly lower world temperature of the Glacial period reacted, and when the temperature had risen to a point where the ice sheet melted faster than it was fed by snow fall, the south margin of the glacier slowly receded and released the land surface. The river grew headward, following the retreating ice front. But the south flow had so deepened the channel at and south of Towanda that the river has retained its southward course.

It appears that the glaciated territory was depressed by the weight of the ice sheet, and when the ice was removed, this area stood below its present, upraised level (figures 1 and 2). The reduced gradient of the rivers assisted by the many drift blockades produced lakes and sluggish waters in many districts. The largest of the Susquehanna lakes were the Wilkes-Barre-Scranton lake in Pennsylvania, and the two lakes in the Binghamton and Elmira districts. Into these waters and the smaller lakes in the upper valley, and in the lower gradient tributaries, the glacial outwash and the land drainage swept a great volume of detritus, left as wide plains of gravel and sand. When the barriers in the lower valley were removed, the lakes were drained and the streams were revived by the tilting rise of the land. The erosion of the plains, whether lake or river deposit, by the rejuvenated drainage has produced the conspicuous benches and terraces along the valley sides.

The valleys of western New York lie in four directions and represent four successive stages in the evolution of the drainage (1) the valleys with southwest trend are the oldest, and are probably inheritances from the early Paleozoic rivers (plate 4); (2) the valleys with east and west direction, as the Mohawk, Ontario and one stretch of the Susquehanna, are of later origin, being subsequent valleys developed by rock control and diverted flow; (3) the north-leading valleys, the Genesee and those of the Finger Lakes district, are of yet later creation, due to the reversed or obsequent flow into the Ontario basin (plate 5); (4) the southeast-leading valleys are the youngest and owe their development to the flow impelled by the ice sheet (plate 6).

It is not possible to correlate closely the stages in the history of the Susquehanna with geologic time periods, but a general reference may be ventured. The primitive southward, or southwestward, flow was established when the area was rising for the last time out of the receding sea, in later Devonian time, and it was extended into Pennsylvania during Pennsylvanian (Carboniferous) time. The date of the beheading by the Mohawk valley is uncertain, perhaps early or middle Tertiary. The capture and westward diversion along the south line of the State was probably later, and may be synchronous with the northward turn through the Seneca valley, which was completed in the latest Tertiary. The southward flow through

Pennsylvania was compelled by the advancing Quebec glacier and confirmed during the removal of the glacier. Whether the river ever had the southward course in Tertiary time is a question.

Doubtless all the large valleys except the first and fourth classes owe their dimensions and form to the erosion in the later Tertiary, even if some of them were outlined during the long peneplanation of the Mesozoic. Drainage in some form and direction covered the territory during the Mesozoic era, and the earliest uplift of the Tertiary probably revived the rivers in their former channels.

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Plate 26

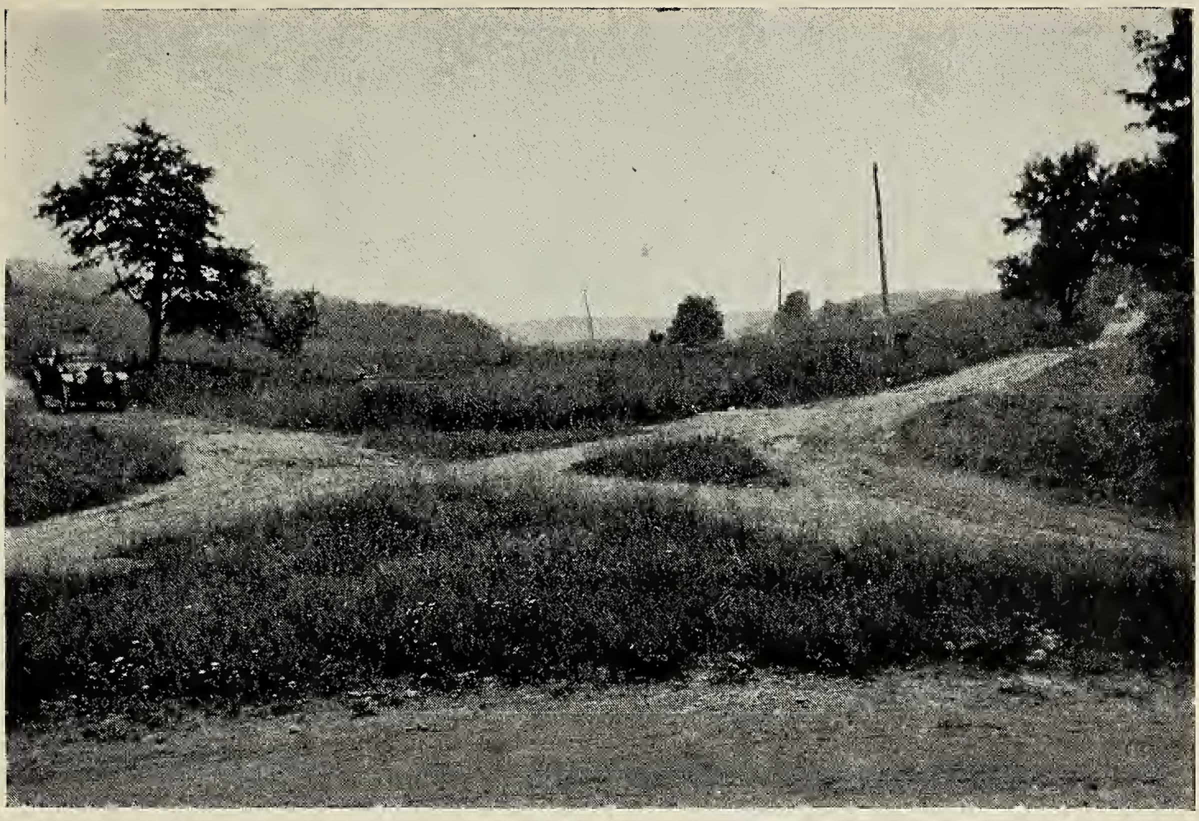

Fig. 1 Rosskelly Corners, 5 miles south of Susquehanna village. Head of the Tunkhannock valley. Looking south.

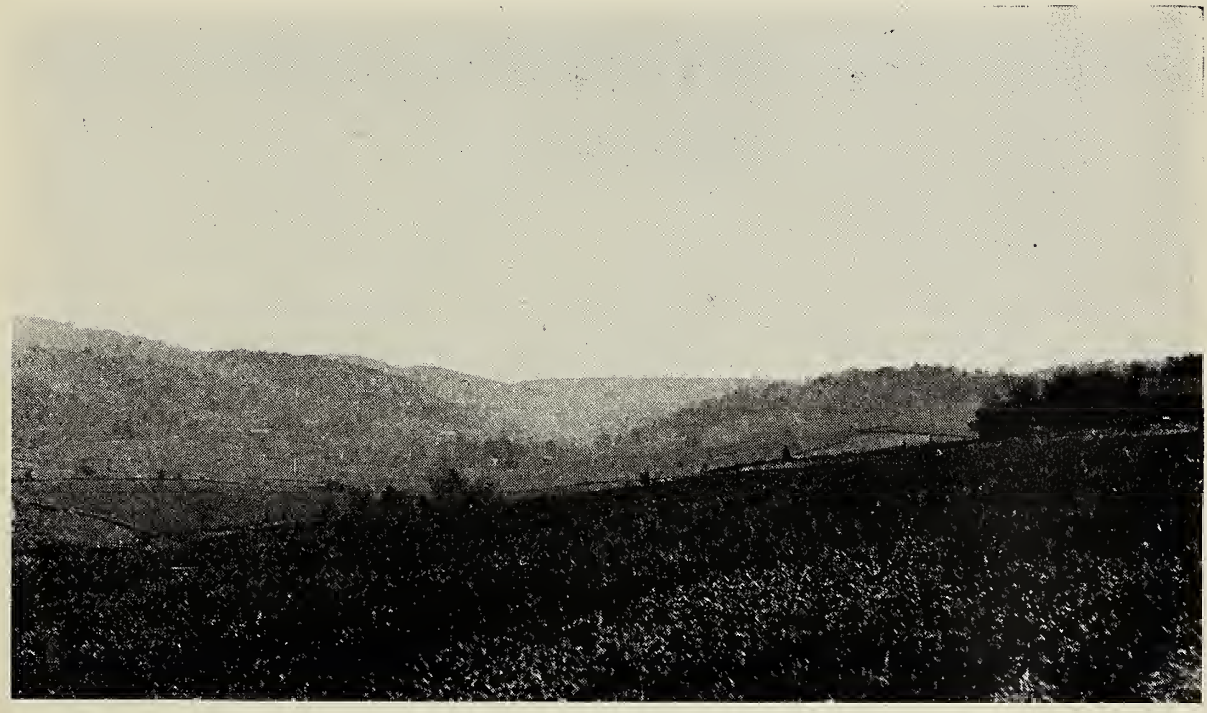

Fig. 2 View looking south down the Tunkhannock valley from point one-fourth mile below Rosskelly Corners.

HEAD OF TUNKHANNOCK VALLEY, THE PATH OF THE PRIMITIVE SUSQUEHANNA

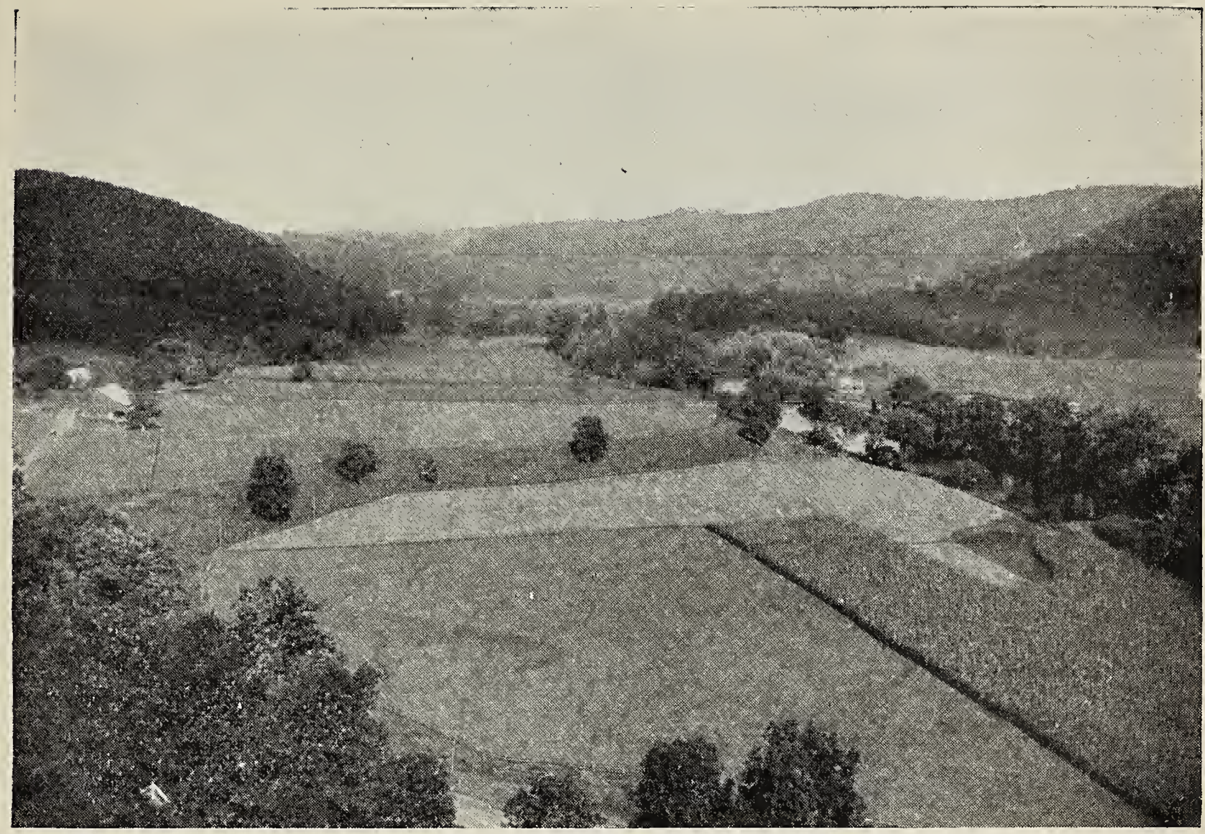

Fig. 1 Tunkhannock valley at Nicholson, Pa., looking east, upstream.

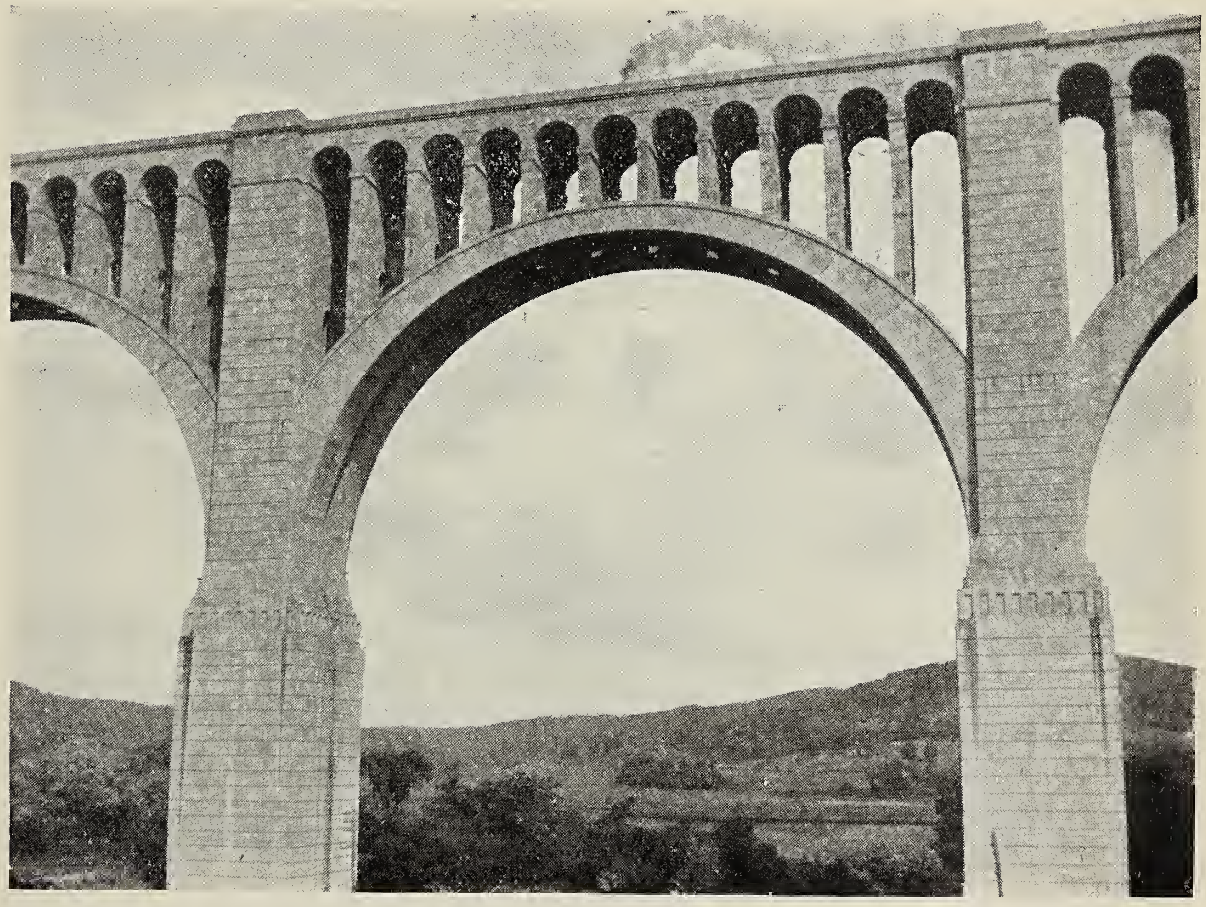

Fig. 2 Viaduct of the Delaware, Lackawanna and Western R. R. across the Tunkhannock valley at Nicholson, Pa.

TUNKHANNOCK VALLEY AT NICHOLSON, PA.

Plate 28

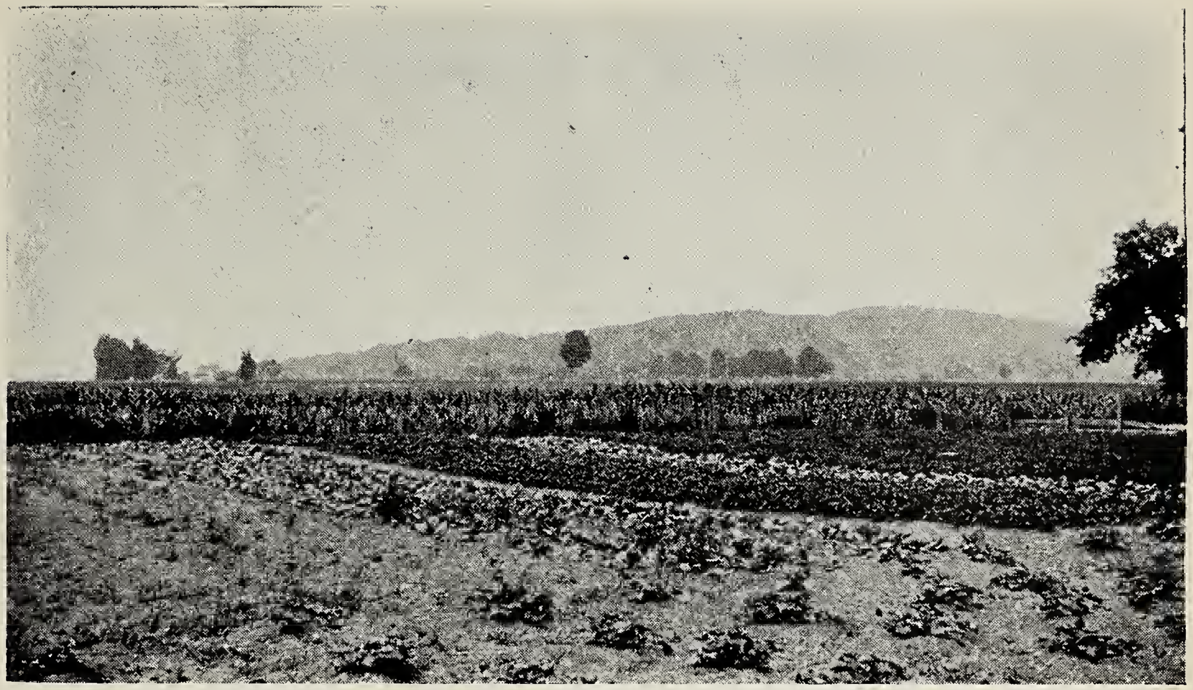

Fig. 1 Delta gravel plain, 2 miles northeast of Horseheads. Looking north. Altitude 940 feet.

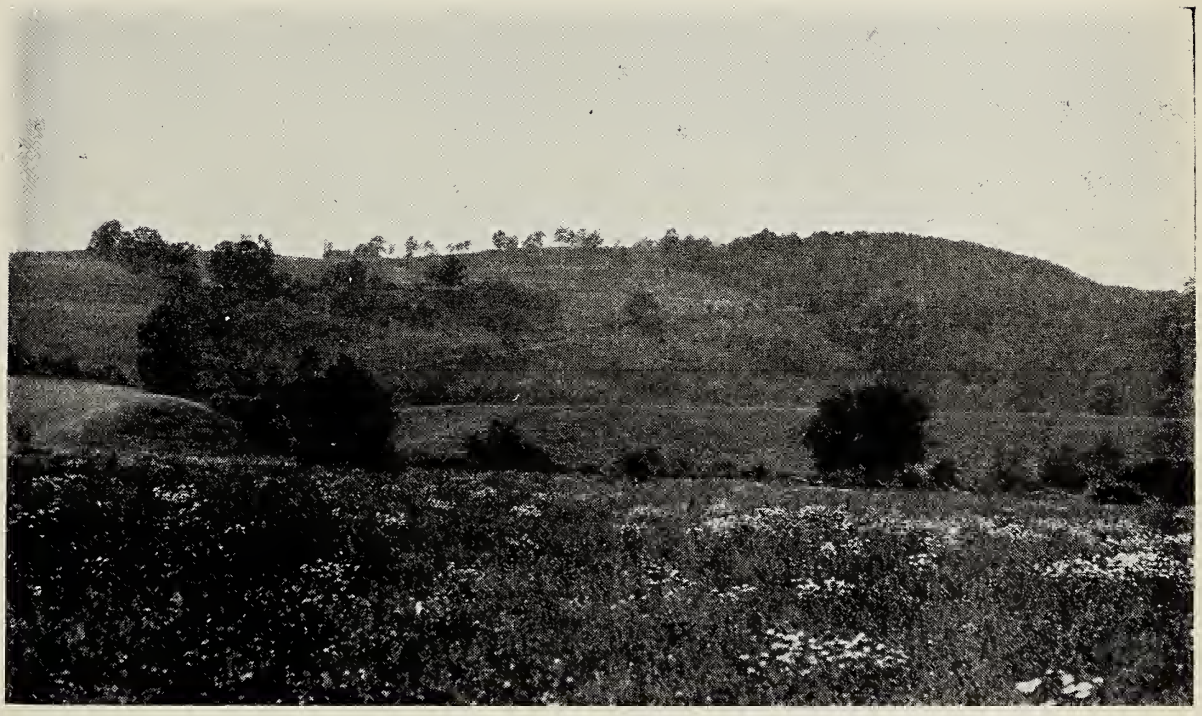

Fig. 2 Terrace southwest of Pine valley. Looking west. Altitude 960 feet.

Detrital Plains of Lake Elmira

Plate 29

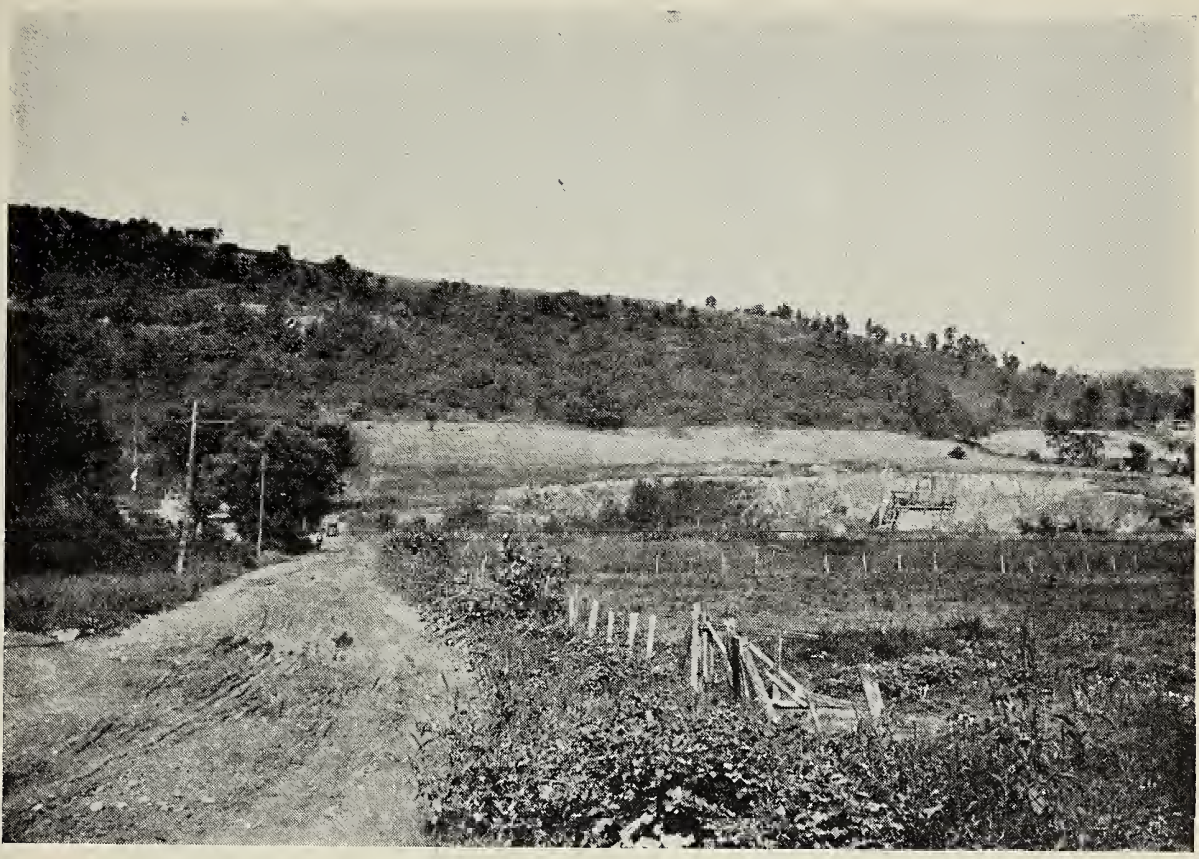

Fig. 1 Remnant of terrace east side of Newtown creek, Elmira. Looking east from bridge over creek at Linden place.

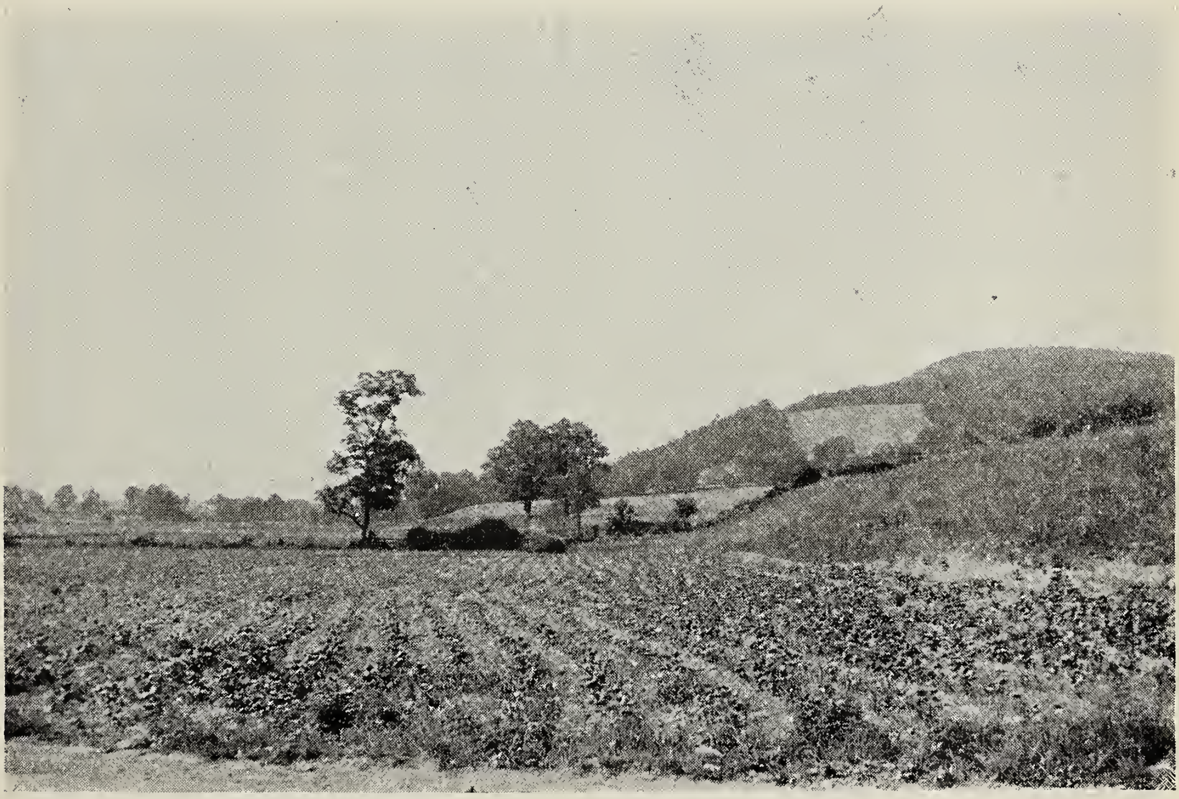

Fig. 2 East bank of Lake Newbury outlet, 2 miles south of Horseheads, by Latta brook road. Looking north. Altitude 890 feet.

FEATURES AT ELMIRA

Plate 30

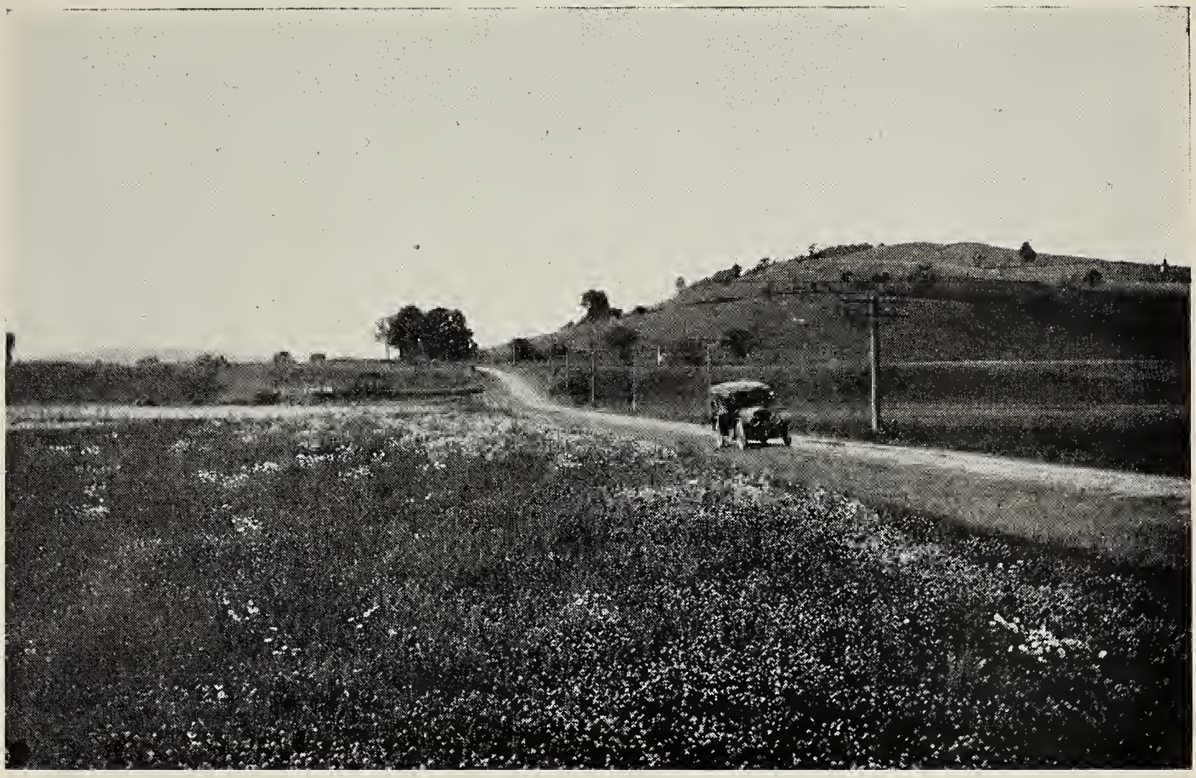

Fig. 1 Terraces at Flemingville, N. Y., at junction of west and east branches of Owego creek. Looking north.

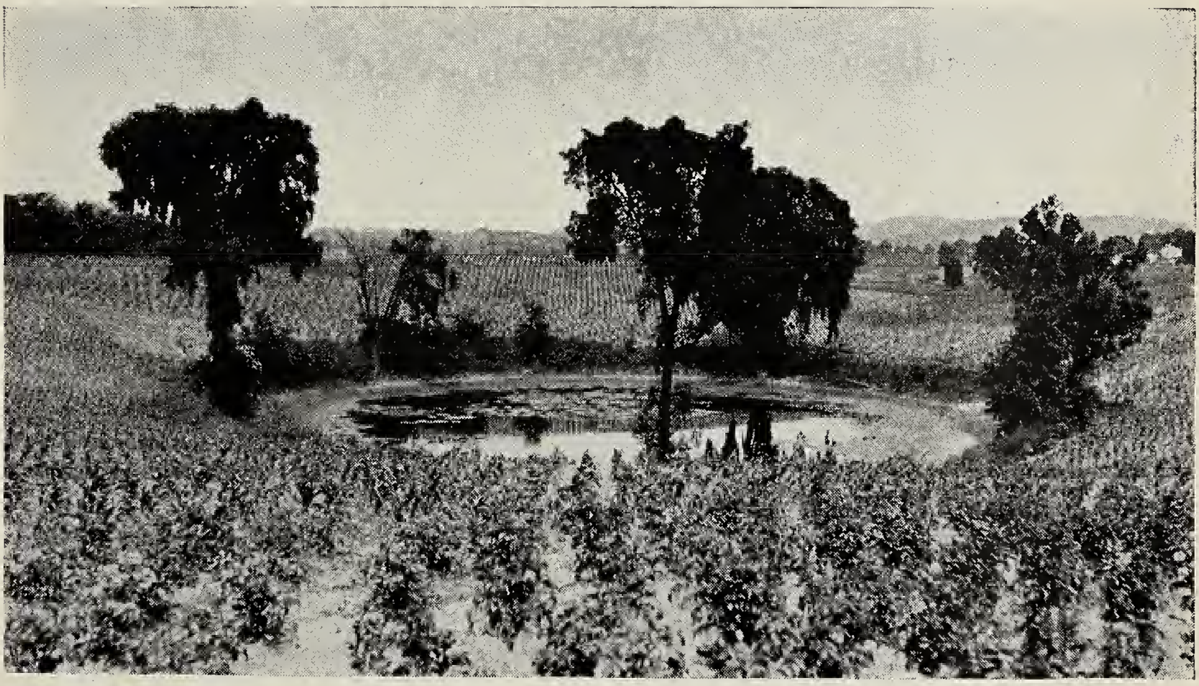

Fig. 2 Ice-block kettle in old flood plain of the Susquehanna river, 3 miles southwest of Owego. Looking north from highway.

Features Near Owego

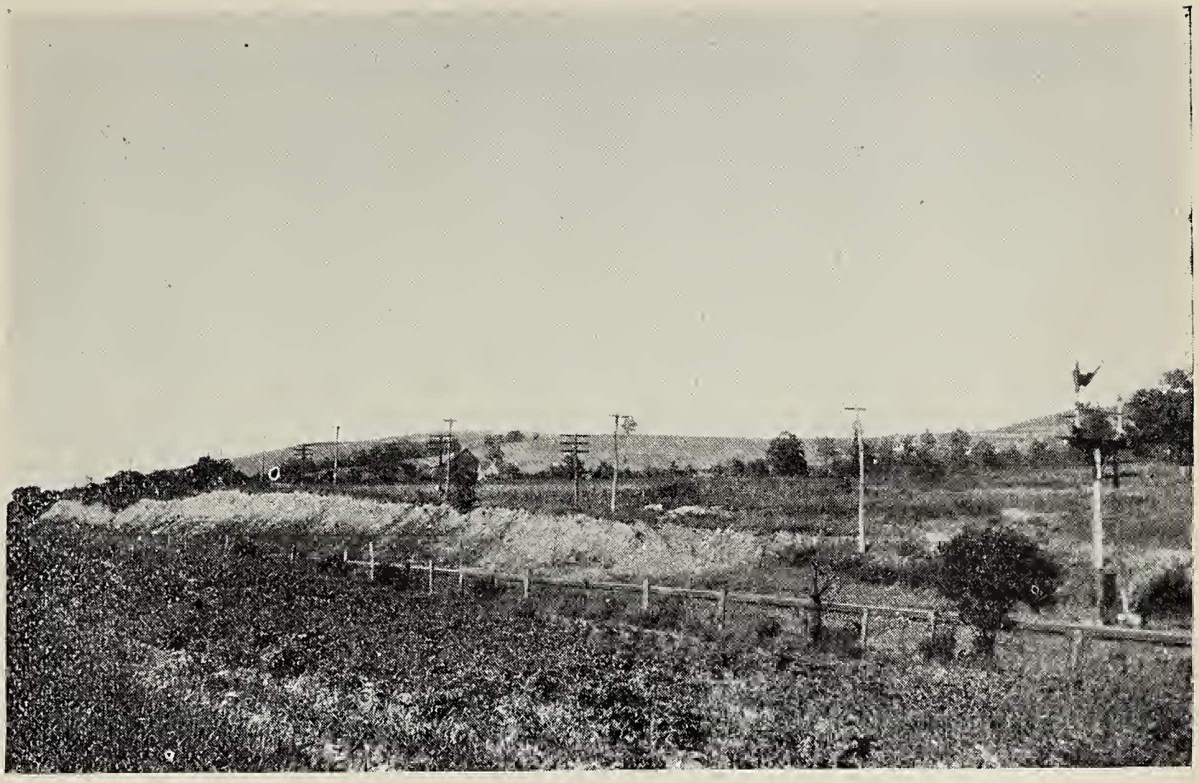

Fig. 1 Cut in delta plain by the Delaware and Hudson R. R., north edge of Binghamton. Looking northeast. Elevation 930 feet.

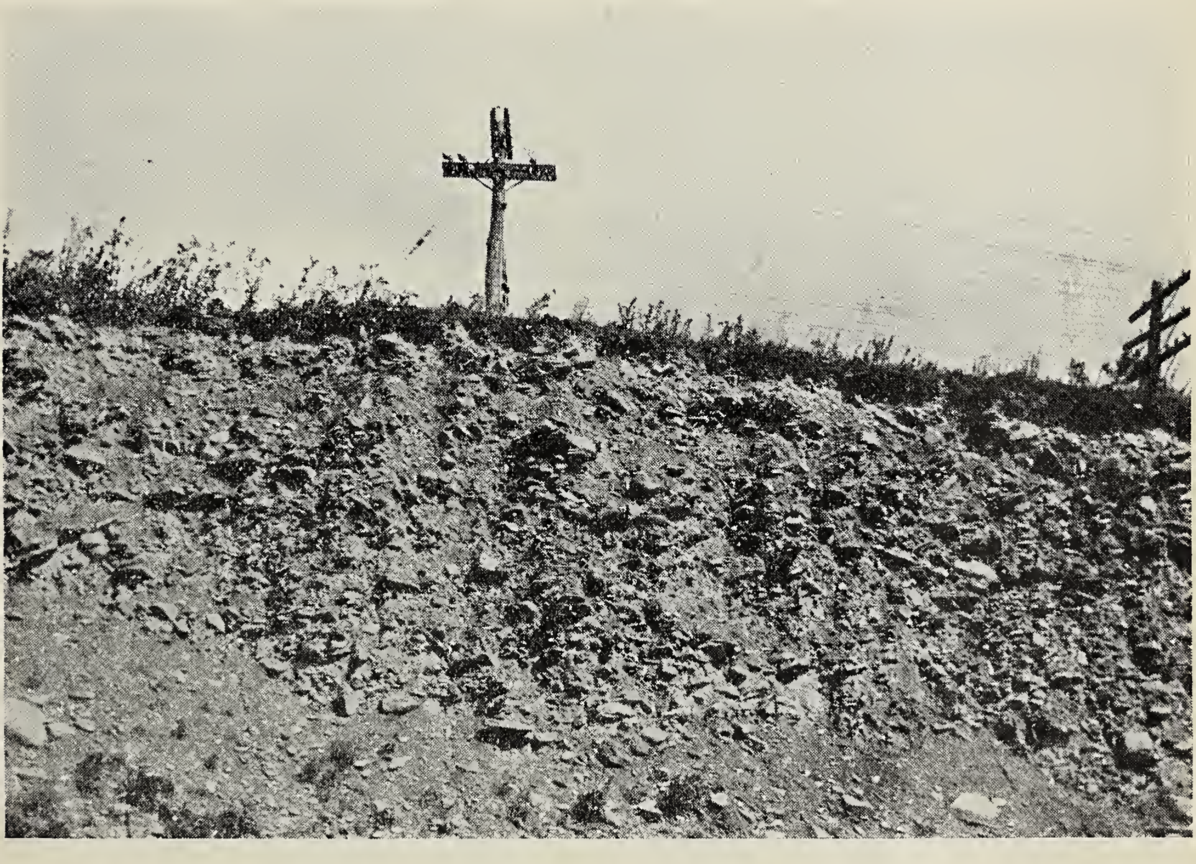

Fig. 2 Close-up view at north end of cut in fig. 1, showing deposit by the torrential stream.

Delta in Binghamton Lake

Plate 32

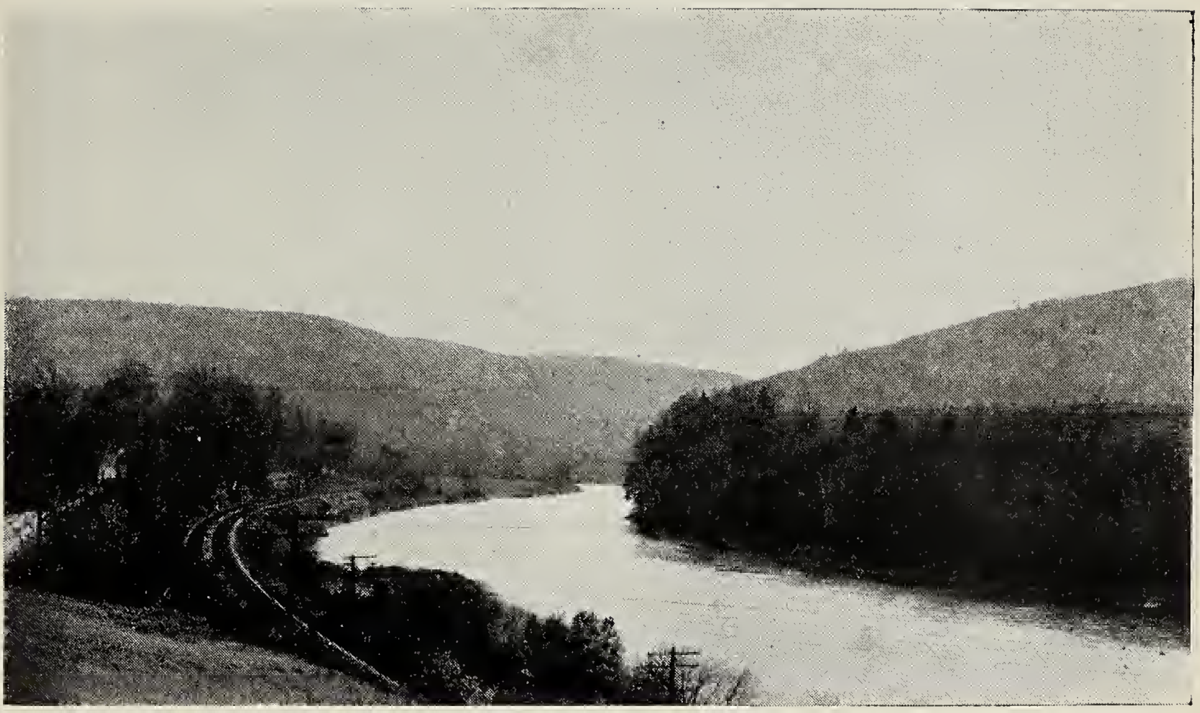

Fig. 1 View looking upstream. Rock cliff at right.

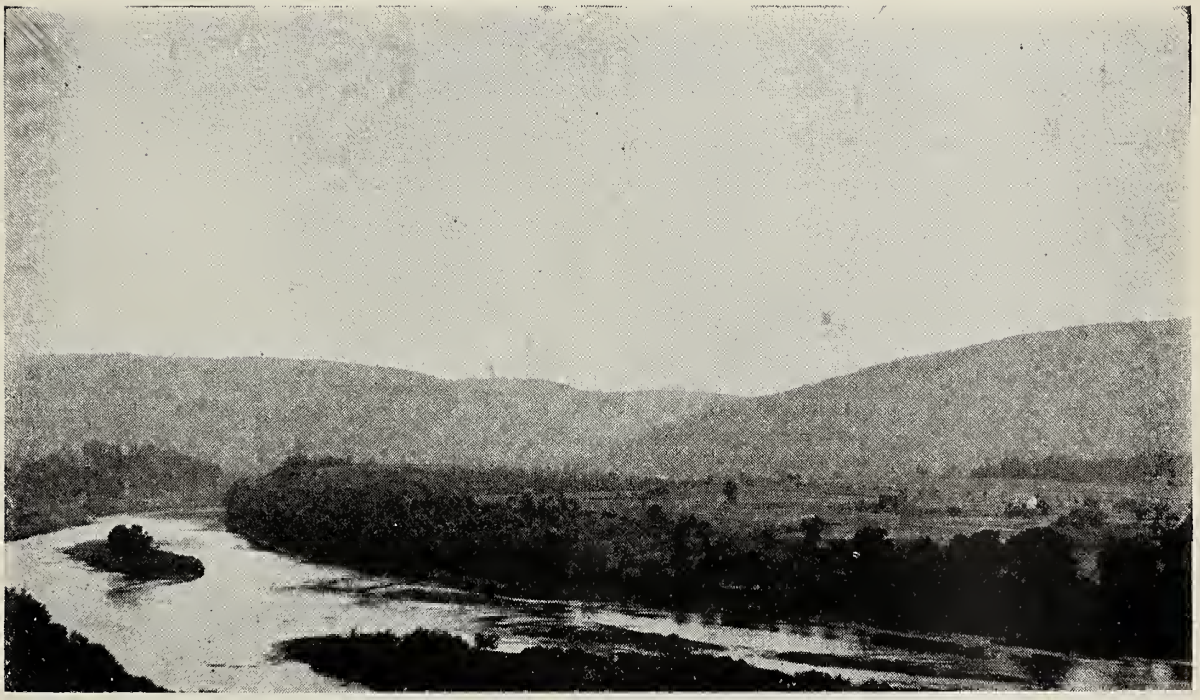

Fig. 2 View looking upstream, Red Rock ravine in the distance.

RED ROCK RAVINE, SUSQUEHANNA RIVER, TWO MILES ABOVE GREAT BEND, PA.

Plate 33

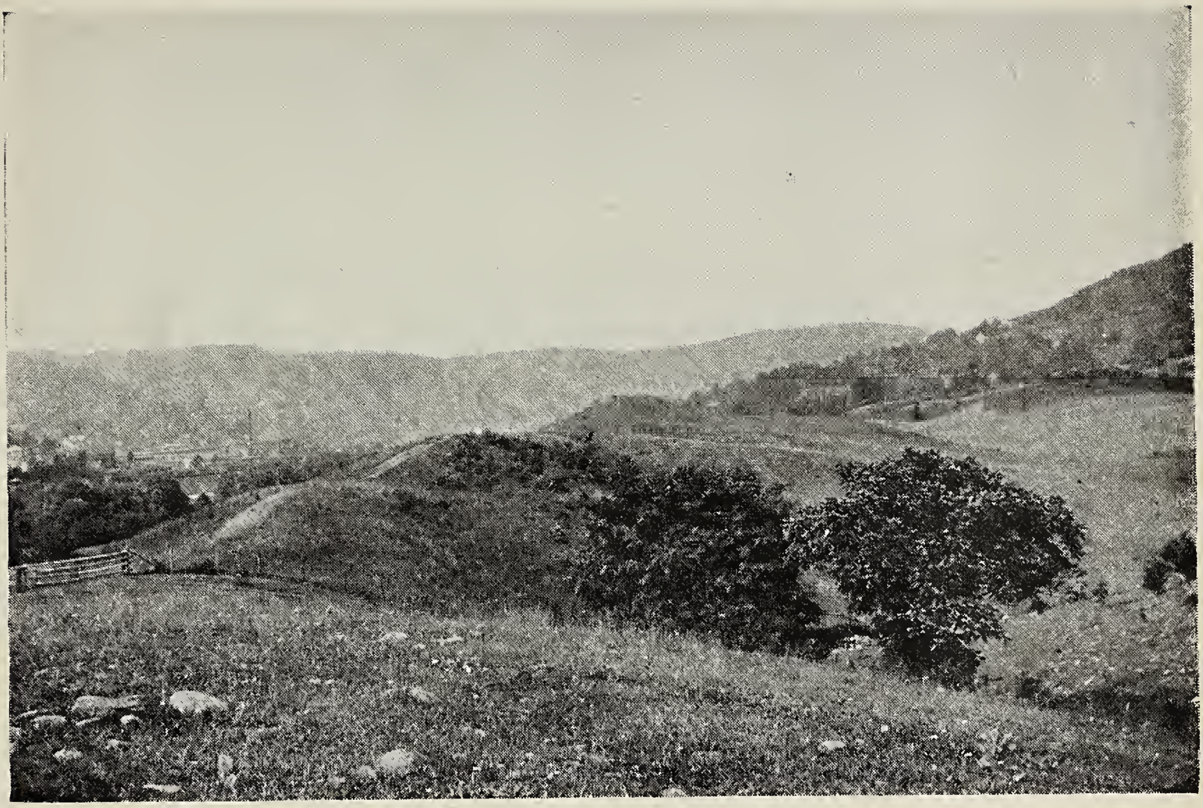

Fig. 1 View looking southwest. River in valley at left.

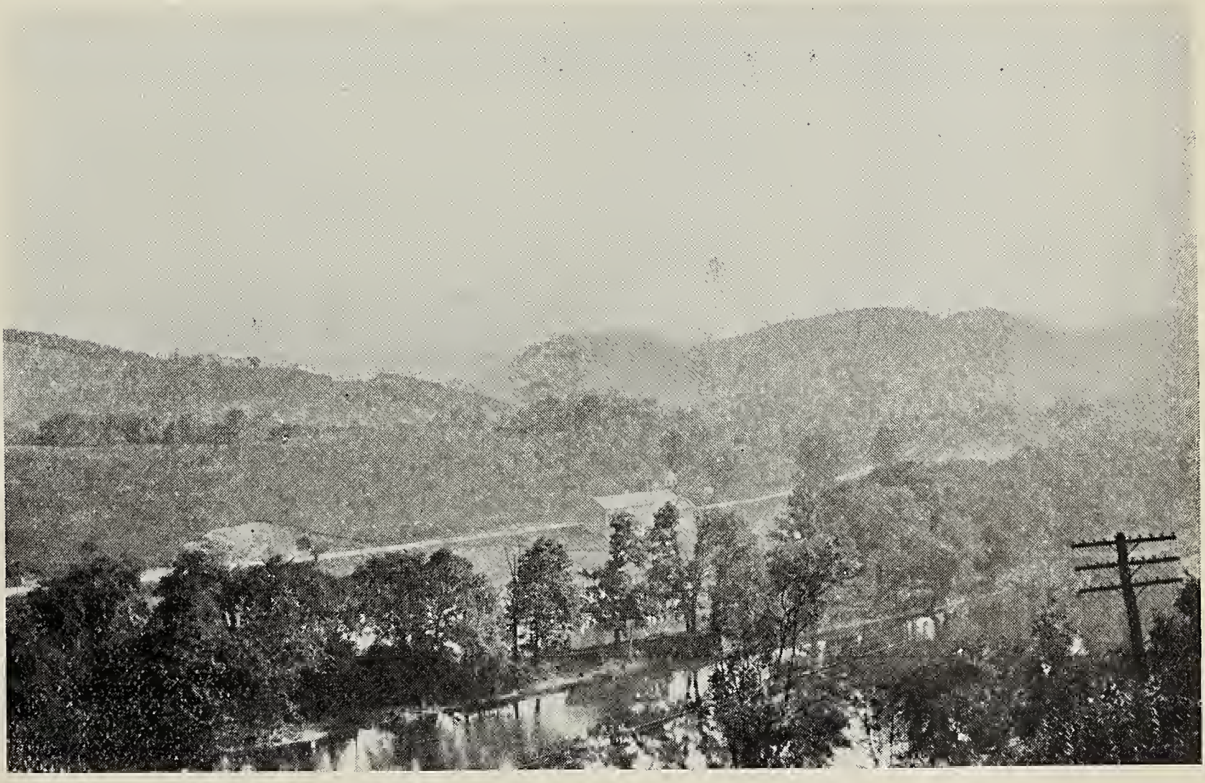

Fig. 2 View looking northeast, across the river, from eastern edge of Susquehanna village.

Esker in Valley of the Susquehanna at Lanesboro, Pa.

Plate 34

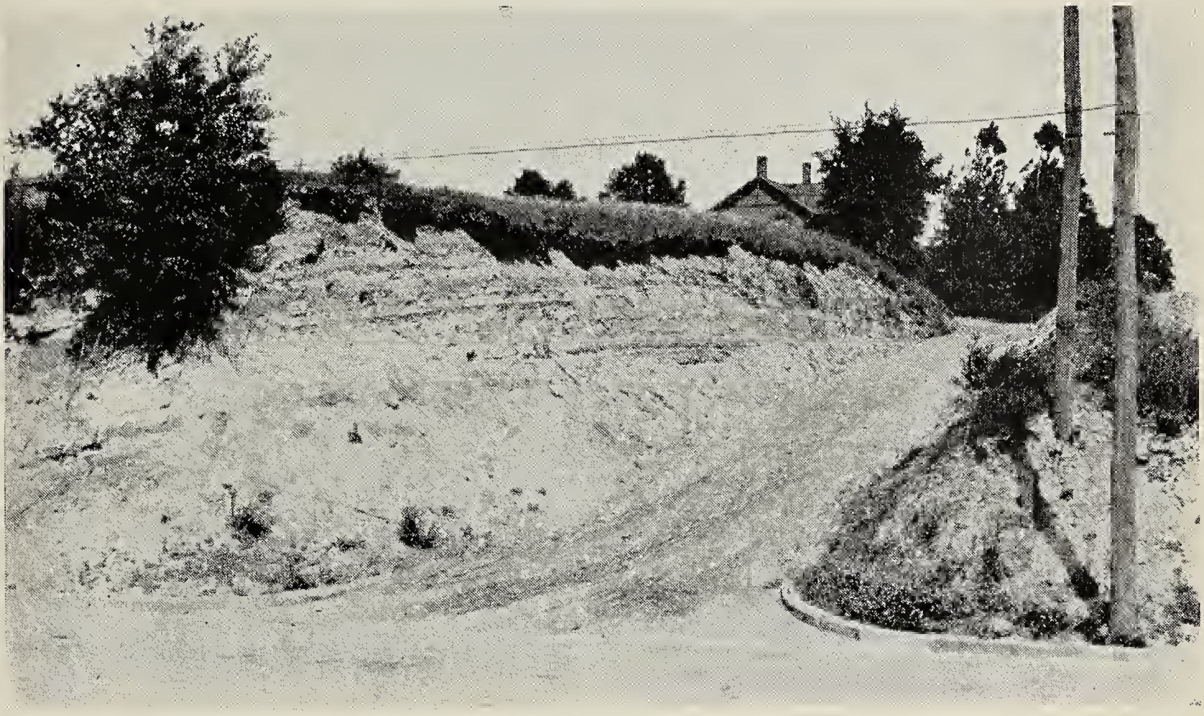

Fig. 1 Highlevel sand beds, South Main and Secor streets, Sidney.

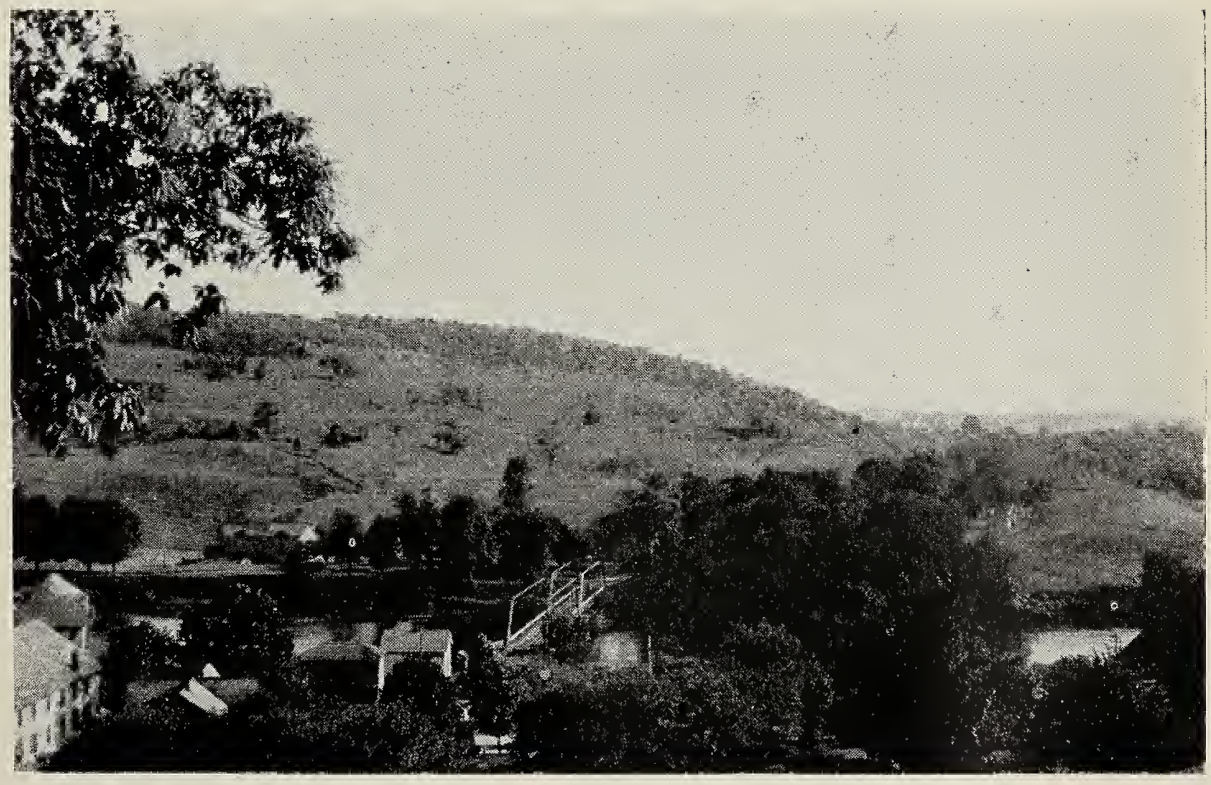

Fig. 2 Terraces at Wells Bridge. Looking southwest, across the river. Summit terrace 1150 feet.

TERRACES AT SIDNEY AND WELLS BRIDGE

Plate 35

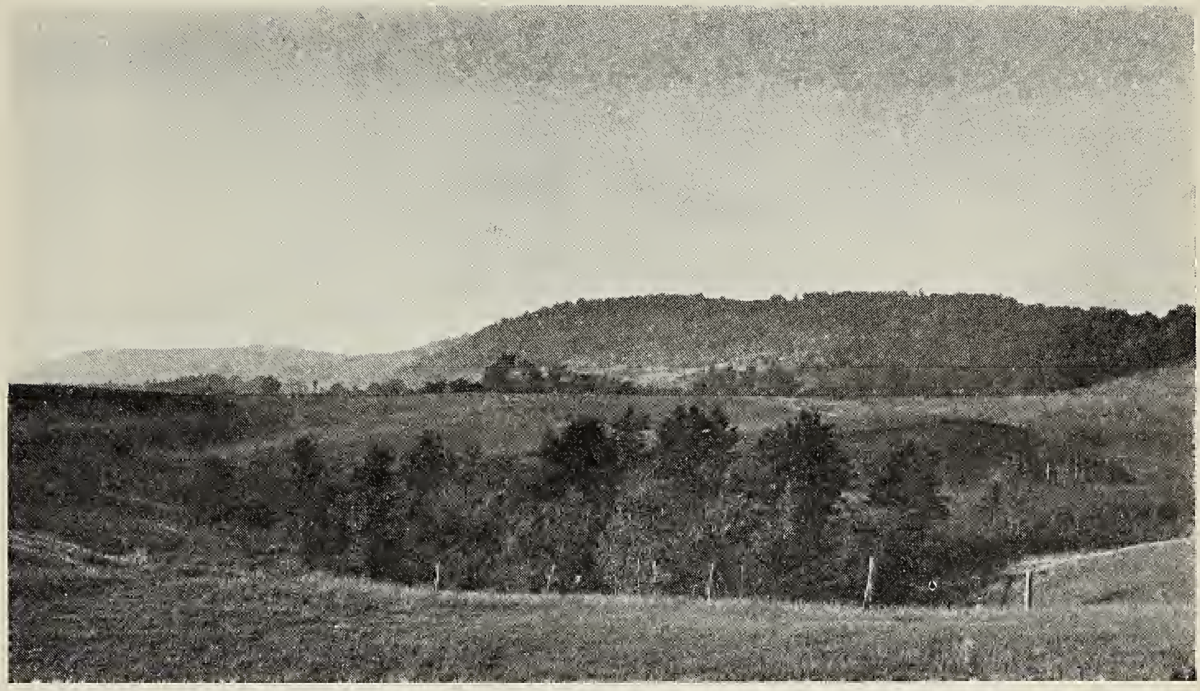

Fig. 1 West of highway. Large basin, looking northwest.

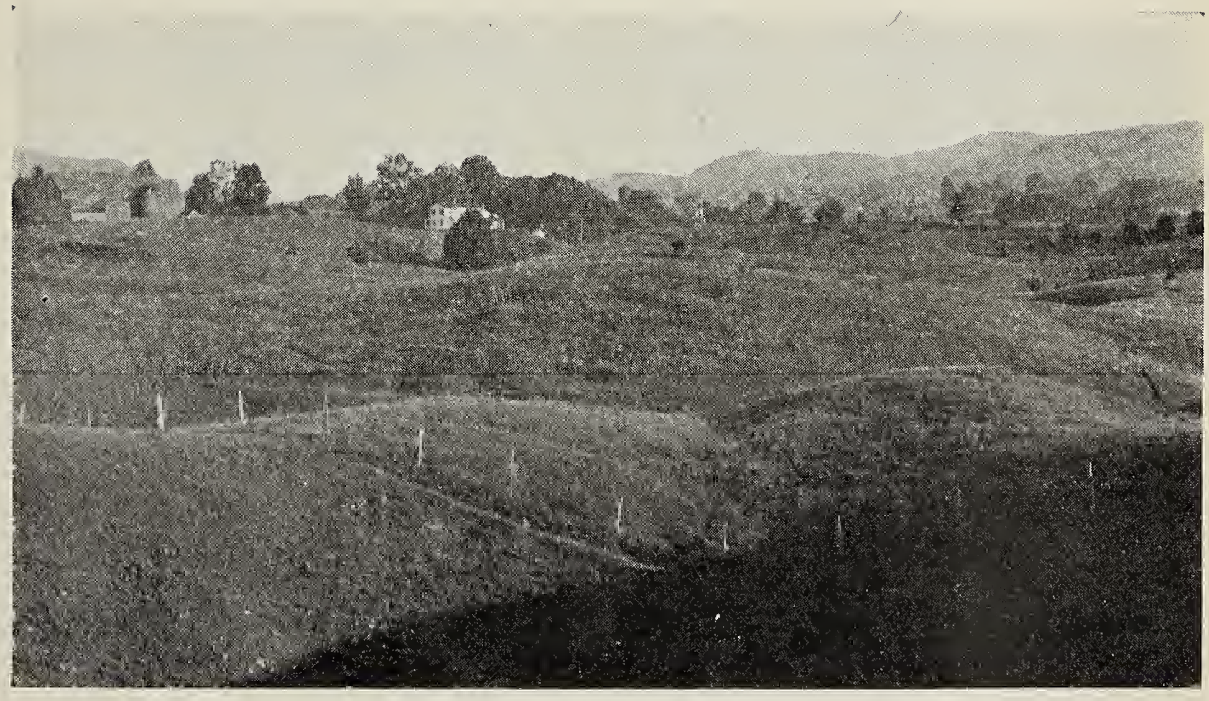

Fig. 2 West of highway. Looking south. Very deep basins in foreground.

KETTLES IN PLAIN AT INDEX, THREE MILES SOUTHWEST OF COOPERSTOWN

Plate 36

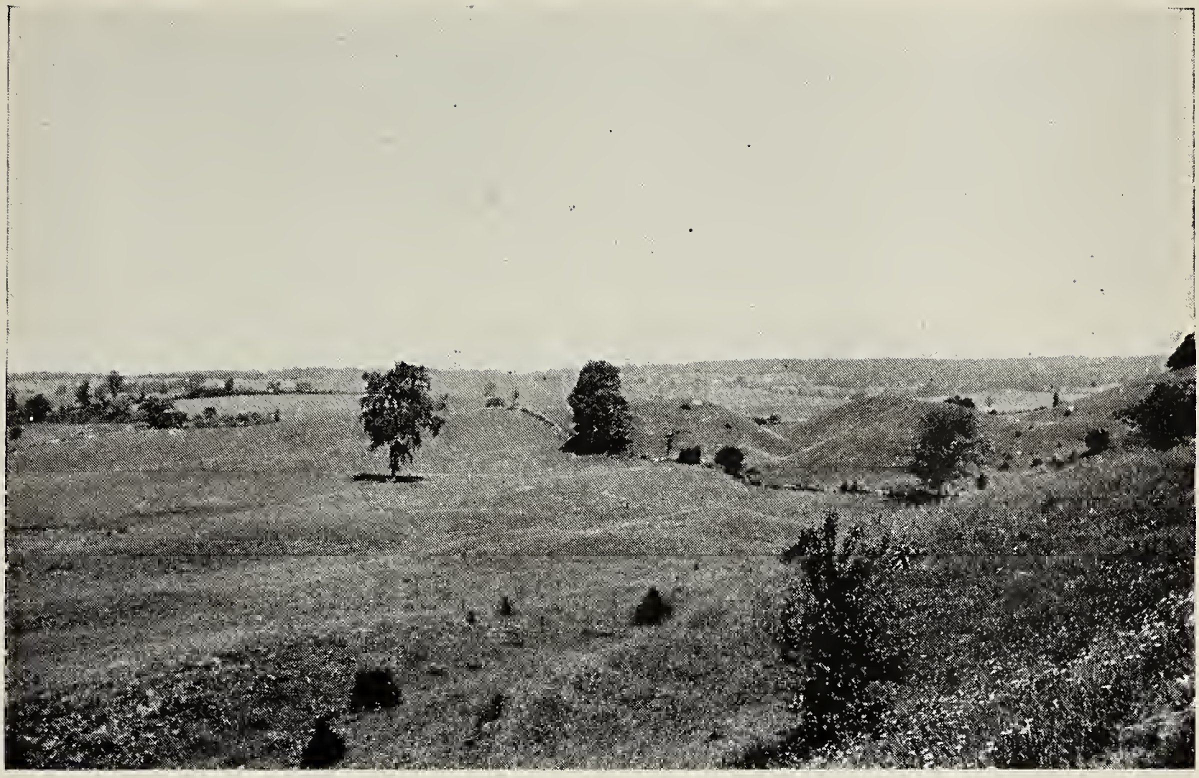

Fig. 1 View looking northwest, from highway, one-half mile east of East Springfield.

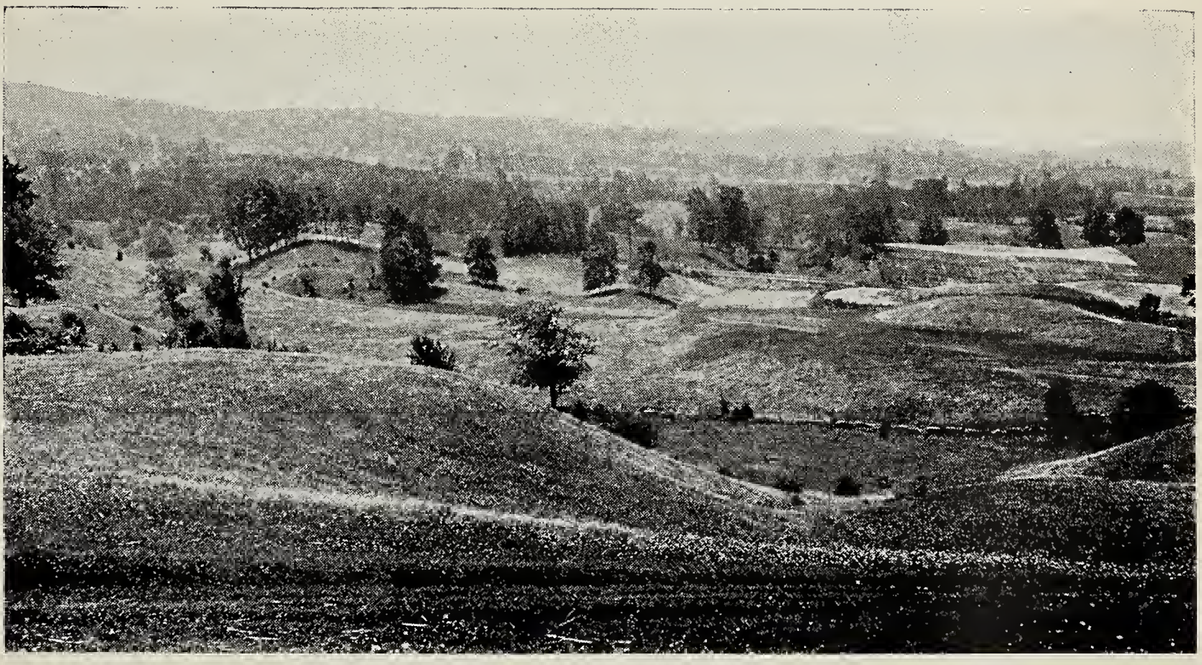

Fig. 2 Looking south from rock knoll one-third mile north of highway.

MORAINE AT EAST SPRINGFIELD

Plate 37

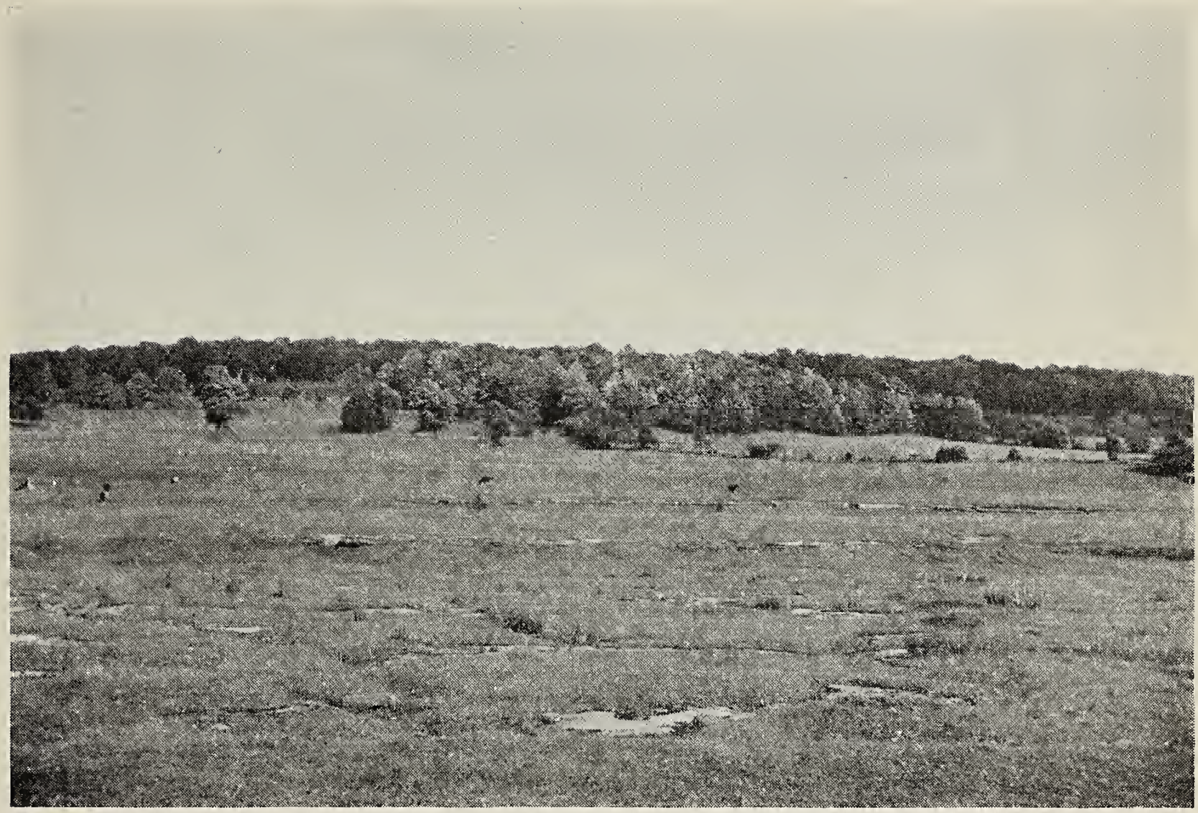

Fig. 1 One mile northeast of East Springfield. Looking east. East bank of glacial river in the background.

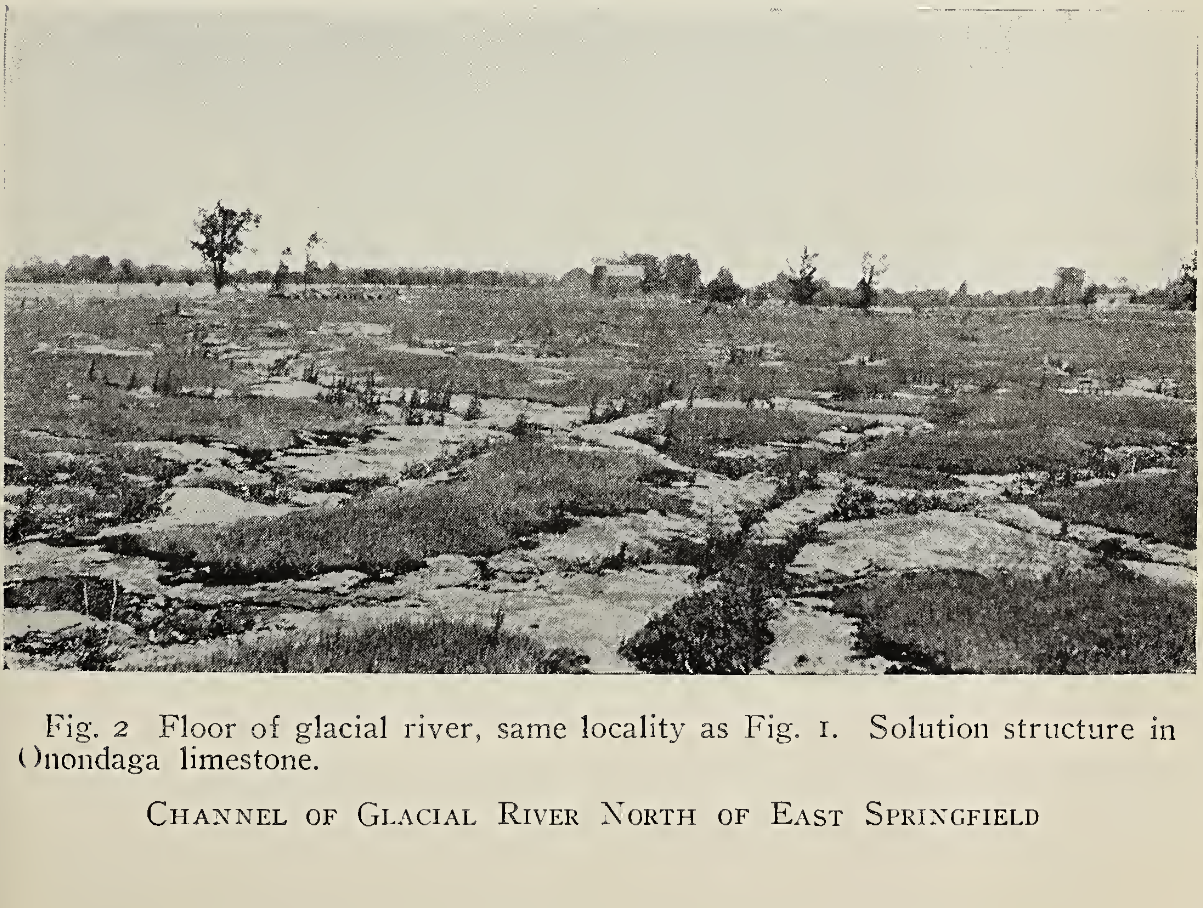

Fig. 2 Floor of glacial river, same locality as Fig. 1. Solution structure in Onondaga limestone.

CHANNEL OF GLACIAL RIVER NORTH OF EAST SPRINGFIELD

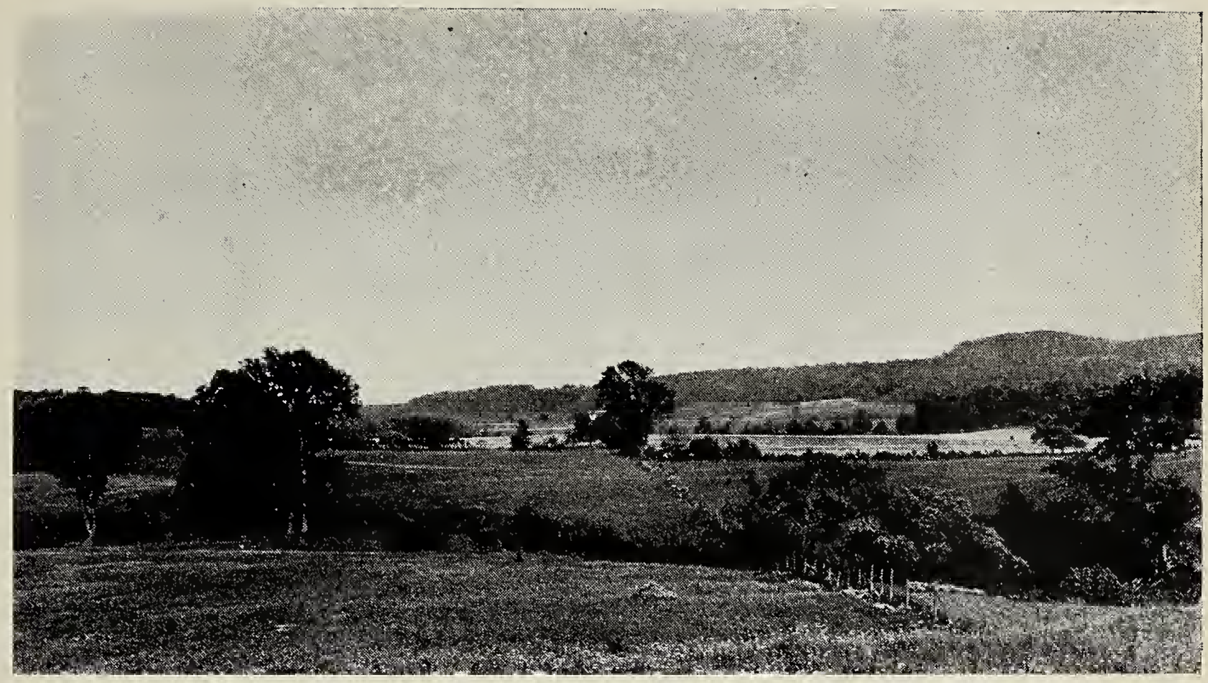

Fig. 1 Plain and terrace, 2½ miles east of north of East Springfield. Looking east from forks of road.

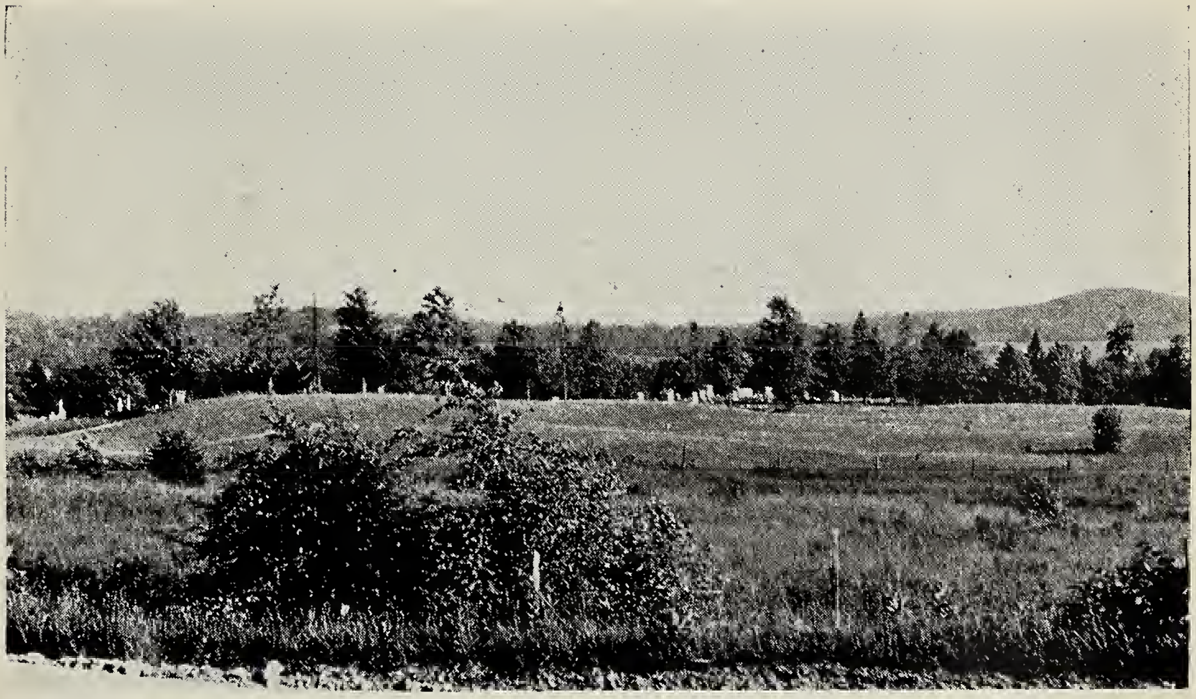

Fig. 2 Delta at Springfield Center, with cemetery. Looking southeast.

GLACIAL DRAINAGE FEATURES NORTH OF OTSEGO LAKE

Plate 39

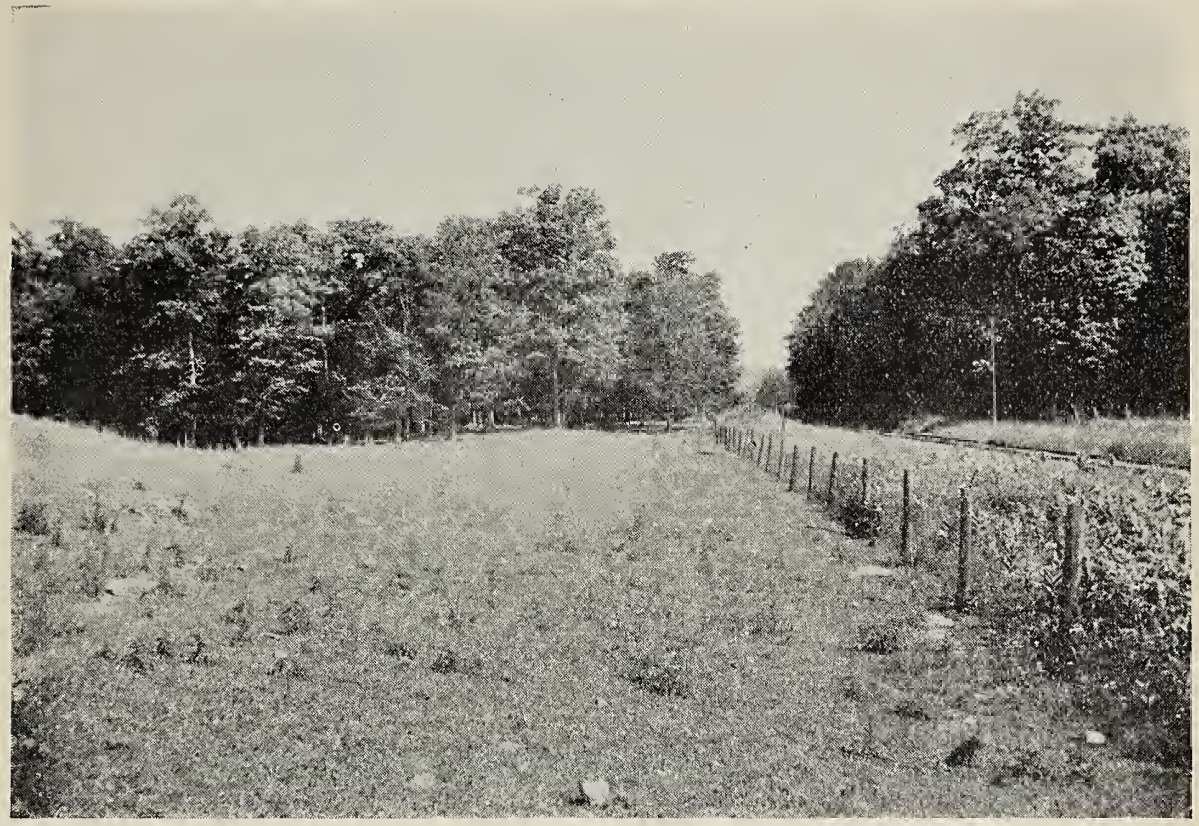

Fig. 1 Divide, and head of channel, 1½ miles northeast of Cherry Valley. Looking north.

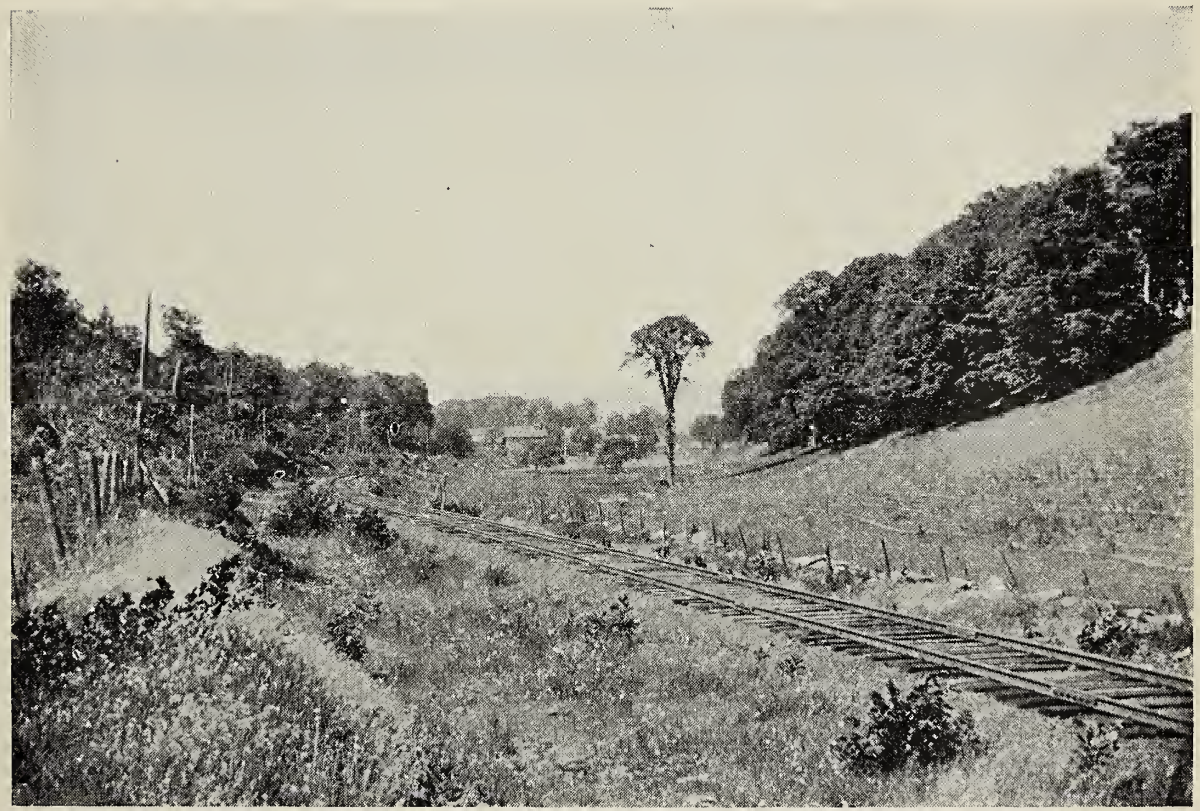

Fig. 2 One-fourth mile south of Fig. 1. Looking south, downstream.

Glacial River Channel at Cherry Valley

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Plate 22 Cols at the Heads of the Unadilla and Chemung Rivers

Plate 23 Corning District

Plate 24 Cohocton Valley

Plate 25 Hornell District; Upper Canisteo Valley

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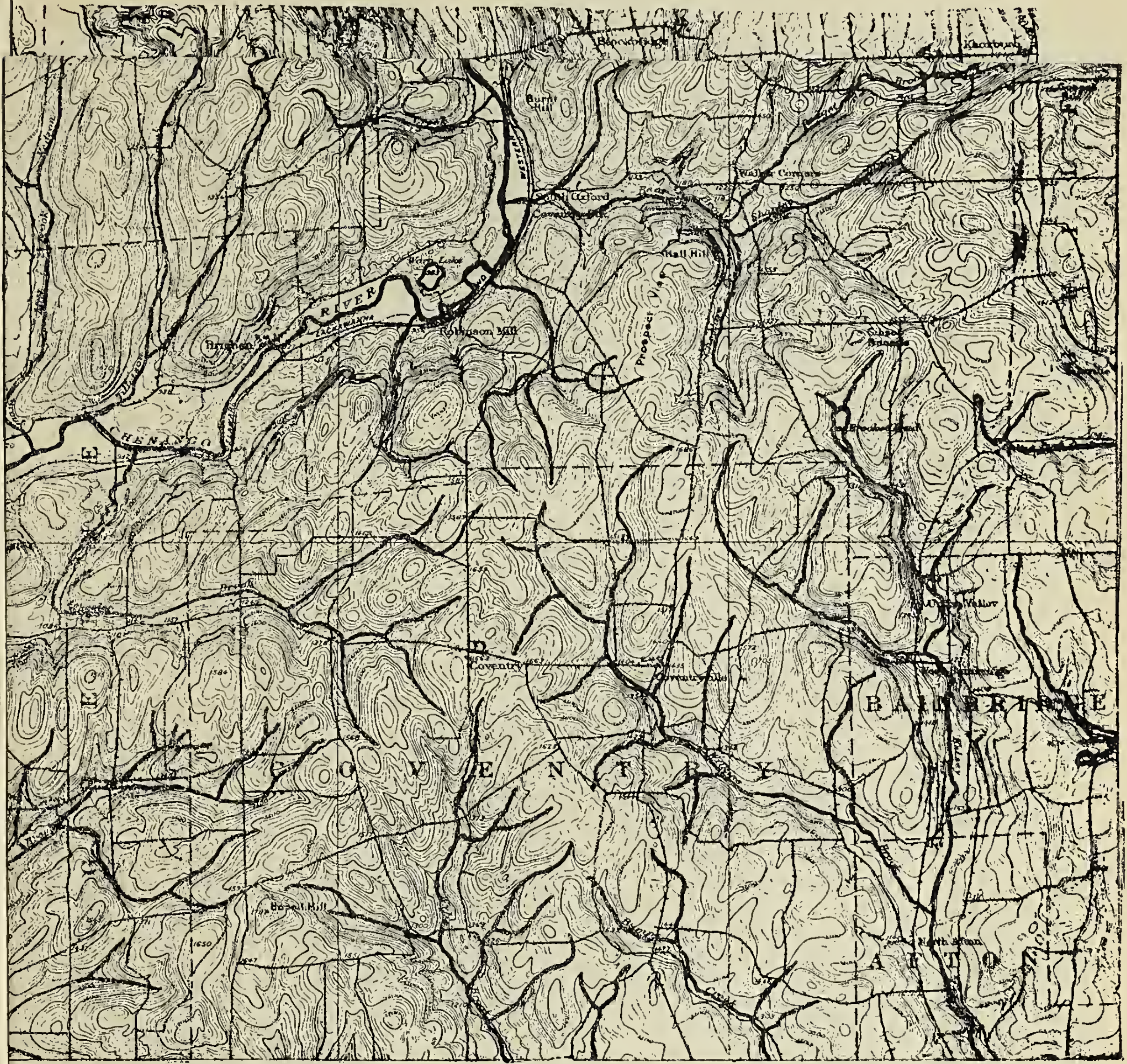
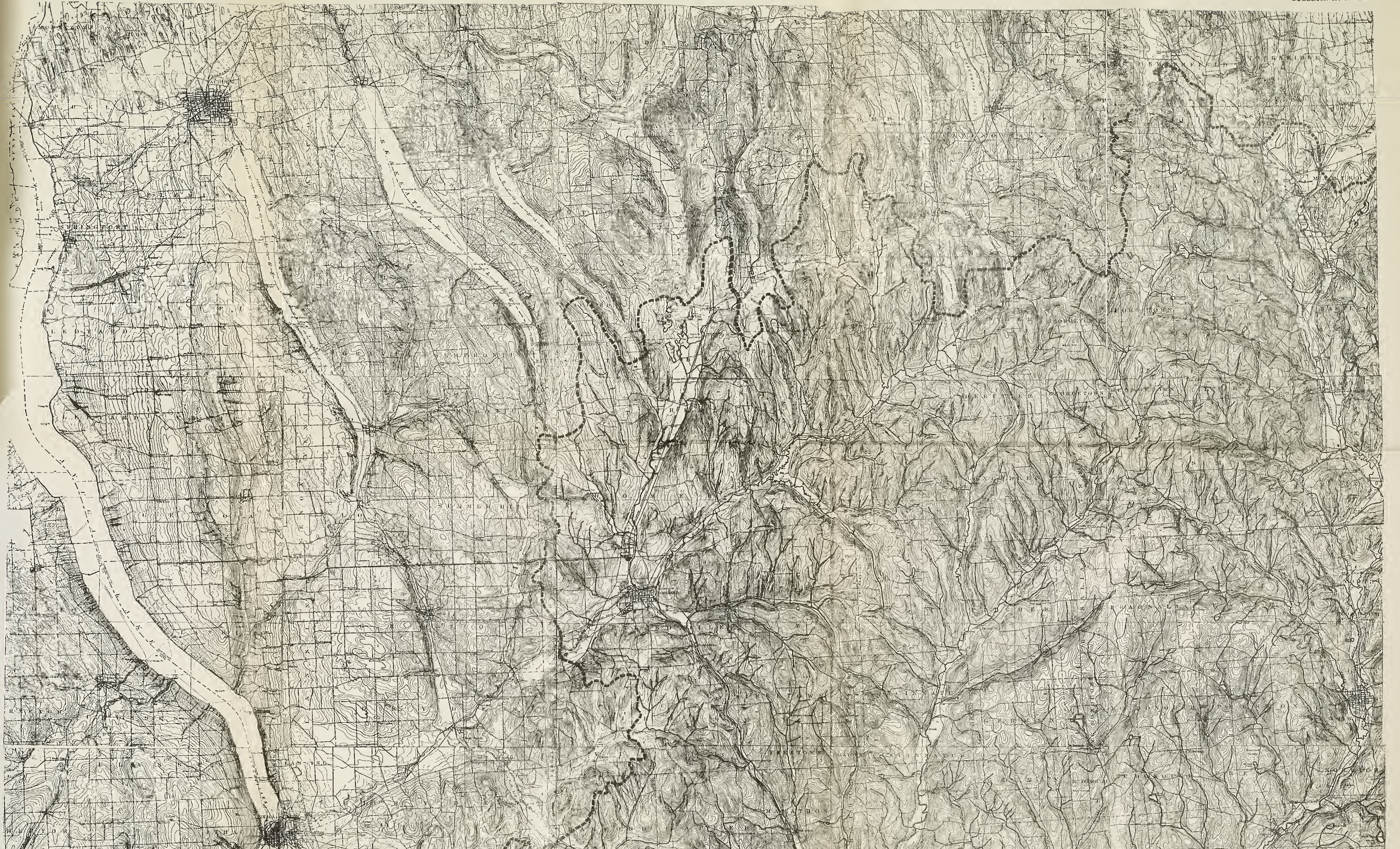
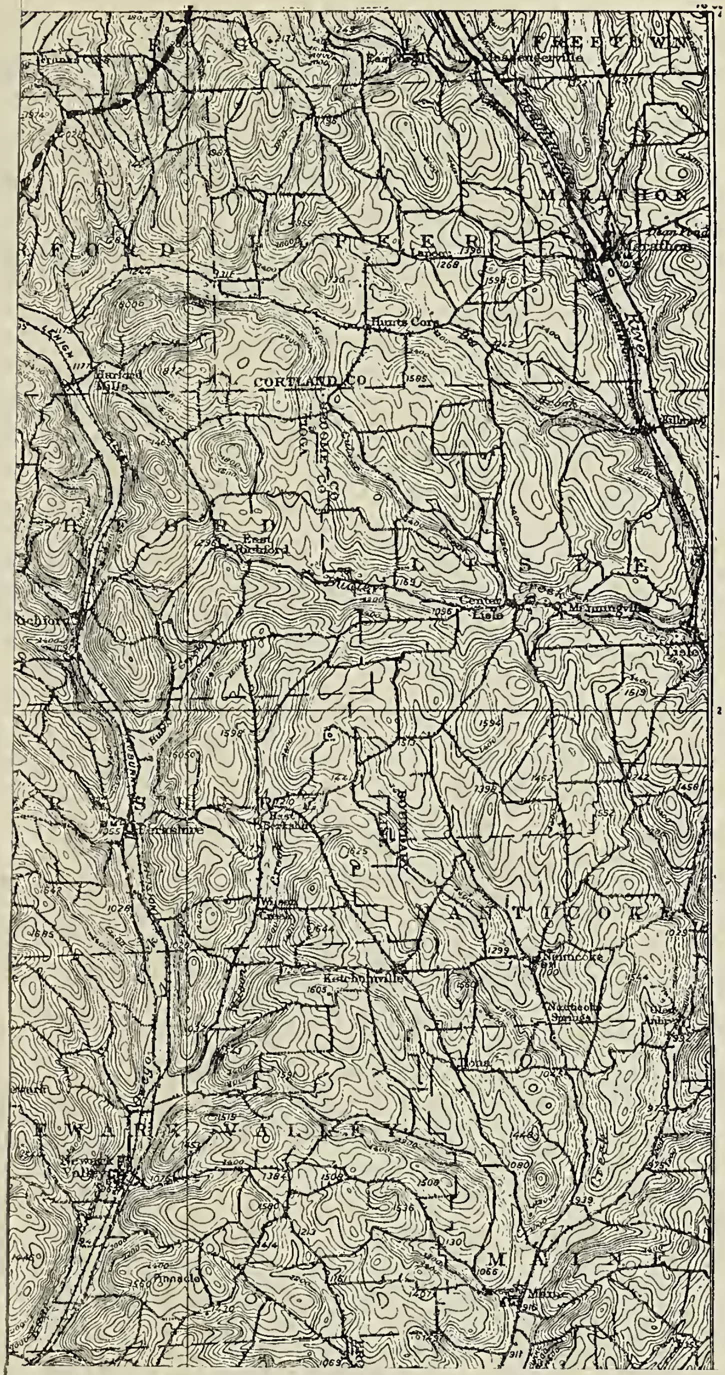
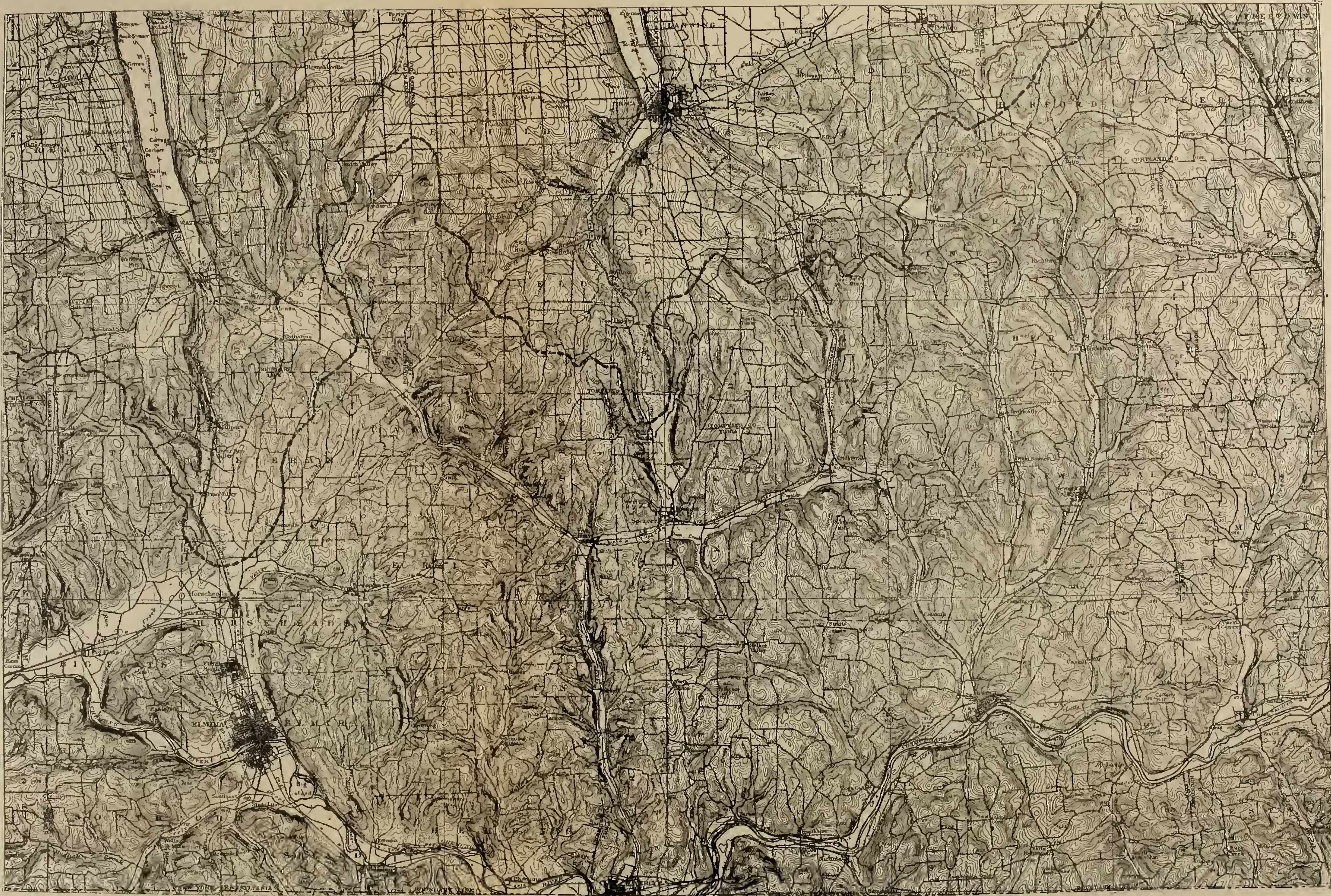




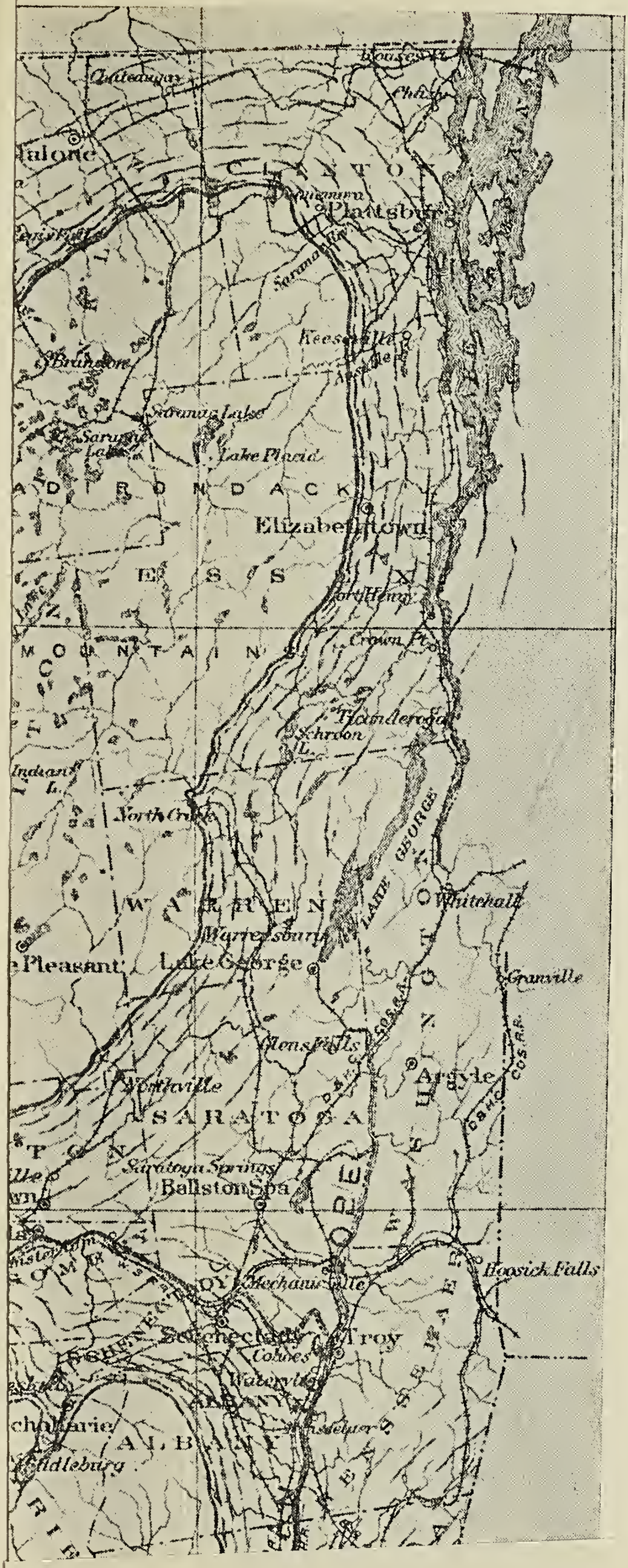
Valleys of Central New York
The broken line is the water parting between the Ontario and the Susquehanna drainage


FREETOWN
Messengerville
MARATHON
Marathon
Hunts Cor.
CORTLAND CO
BROOME CO
Harford Mills
East Richford
Center Lisle
Killawog
Lisle
Berkshire
East Berkshire
Whitney Point
NANTICOKE
Nanticoke
Nanticoke Springs
Ketchumville
NEWARK VALLEY
Newark Valley
Pinnacle
MAINE
Maine
Glen Aubrey

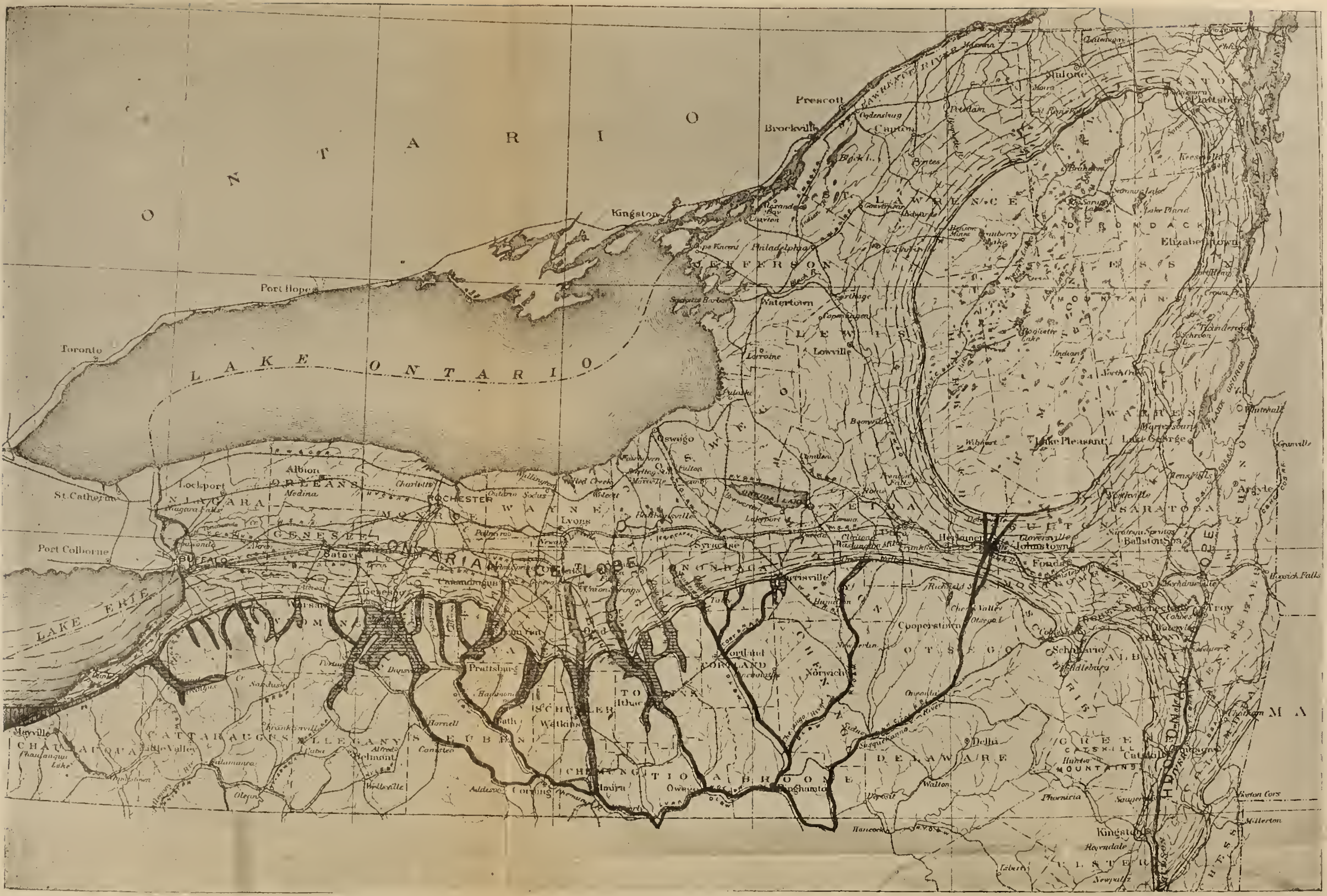


VALLEYS OF SOUTH-CENTRAL NEW YORK

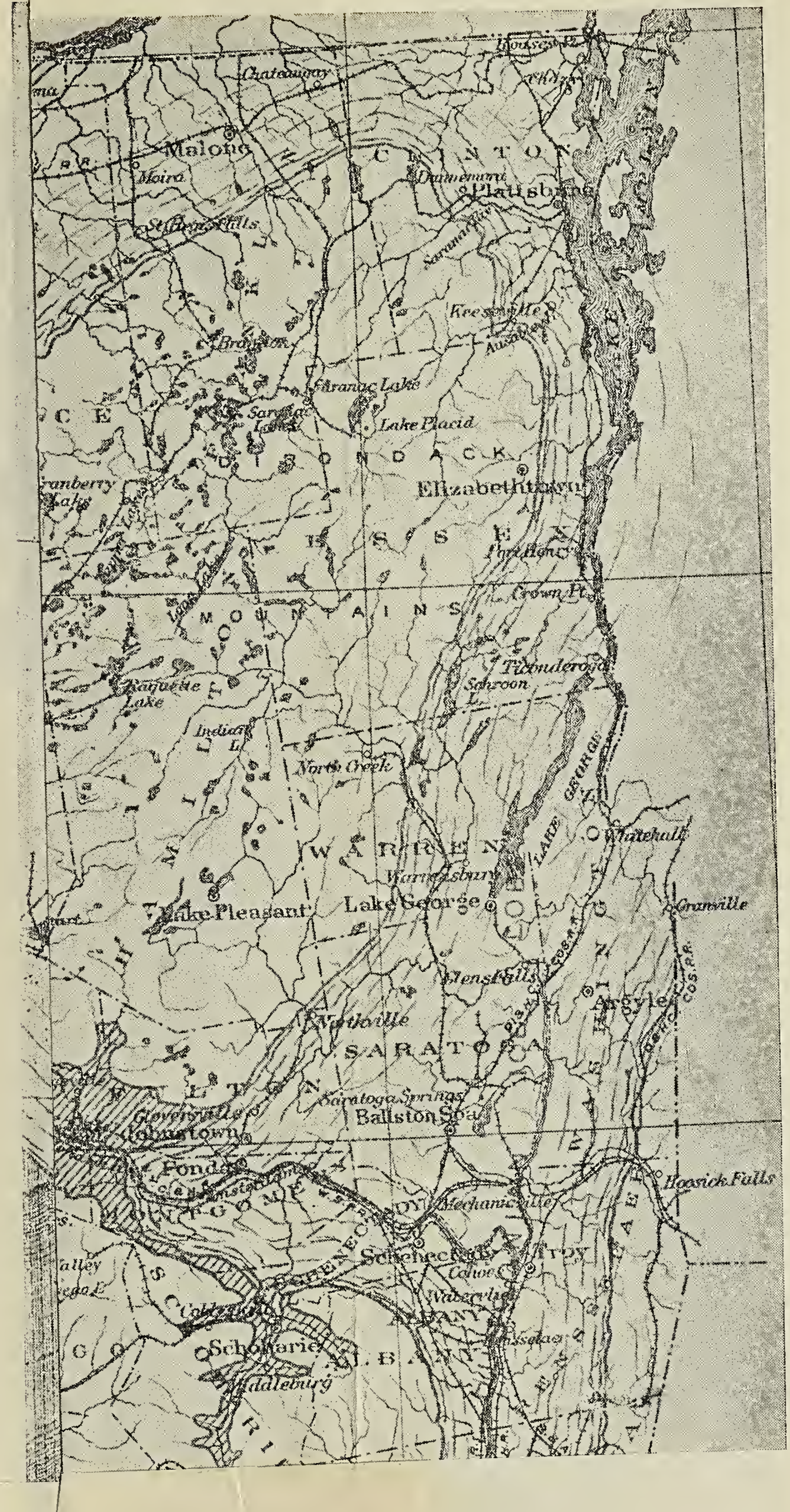
The broken line marks the divide between Ontario and Susquehanna drainage

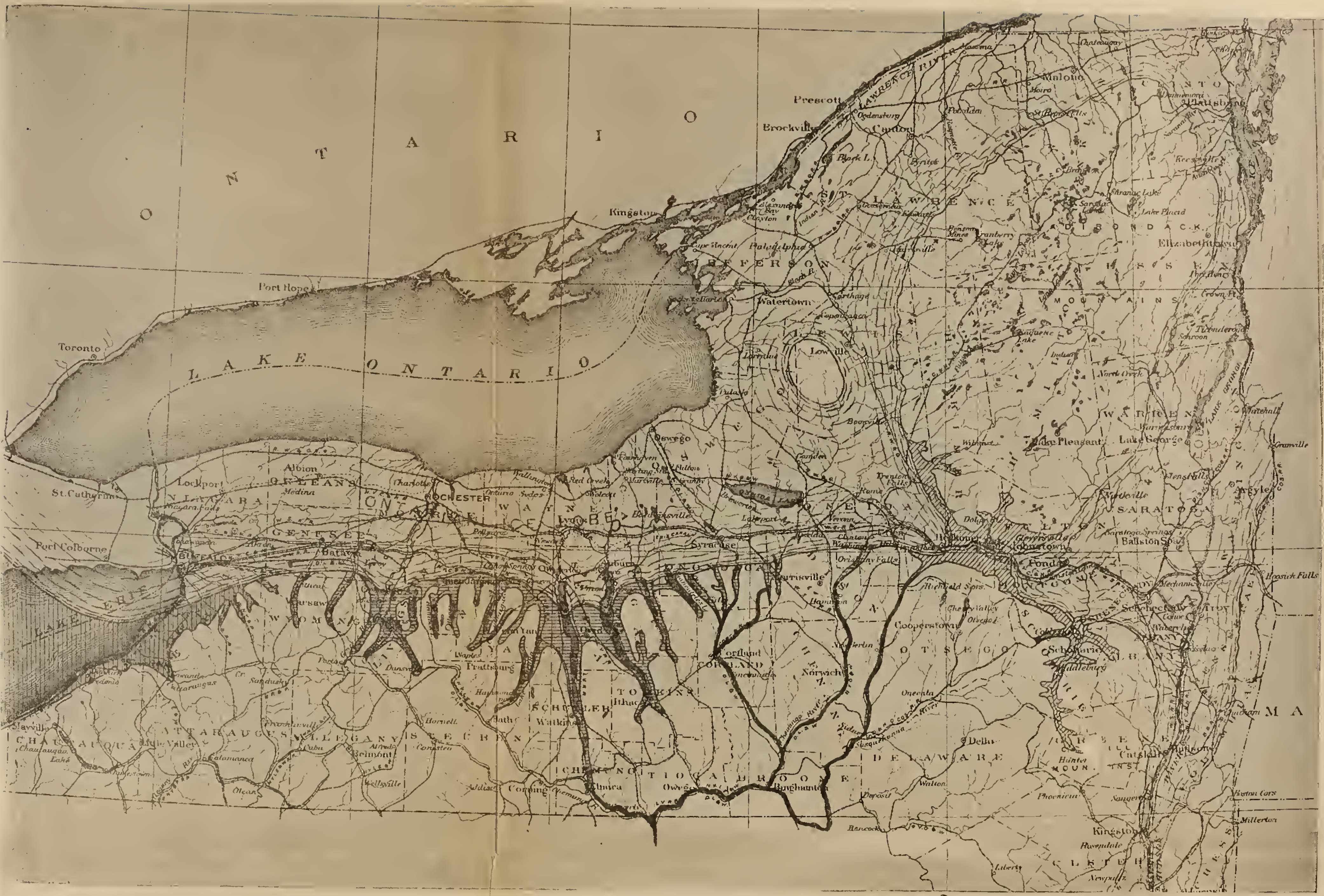


Chateaugay
Rouses Pt.
Chazy
Malone
CLINTON
Dannemora
Plattsburg
Saranac R.
Keeseville
Ausable R.
Brandon
Saranac Lake
Saranac L.
Lake Placid
ADIRONDACK
Elizabethtown
ESSEX
Port Henry
Crown Pt.
MOUNTAINS
Ticonderoga
Schroon L.
Indian L.
North Creek
LAKE GEORGE
WARREN
Warrensburg
Whitehall
Pleasant
Lake George
Granville
Glens Falls
Argyle
Northville
SARATOGA
WASHINGTON
Saratoga Springs
Ballston Spa
Mechanicville
Hoosick Falls
Schenectady
Troy
Cohoes
Watervliet
ALBANY
Rensselaer
RENSSELAER
Schoharie
Middleburg



Closing Phase of the Glacial Susquehanna


Chateaugay
Rouses Pt.
Malone
Moira
C L I N T O N
Dannemora
Plattsburg
St. Regis Falls
Saranac R.
Brandon
Keeseville
Ausable
Saranac Lake
Lake Placid
Saranac Lake
C E
A D I R O N D A C K
Cranberry Lake
Elizabethtown
E S S E X
Port Henry
Crown Pt.
M O U N T A I N S
Raquette Lake
Ticonderoga
Schroon L.
Indian L.
North Creek
LAKE GEORGE
Whitehall
W A R R E N
Warrensburg
Lake George
Lake Pleasant
Granville
Glens Falls
Argyle
Northville
S A R A T O G A
Saratoga Springs
Ballston Spa
Gloversville
Johnstown
Fonda
Amsterdam
M O N T G O M E R Y
Mechanicville
Hoosick Falls
Schenectady
Troy
Cohoes
Watervliet
ALBANY
Rensselaer
Cobleskill
Schoharie
A L B A N Y
Middleburg



Susquehanna River in Greatest Volume

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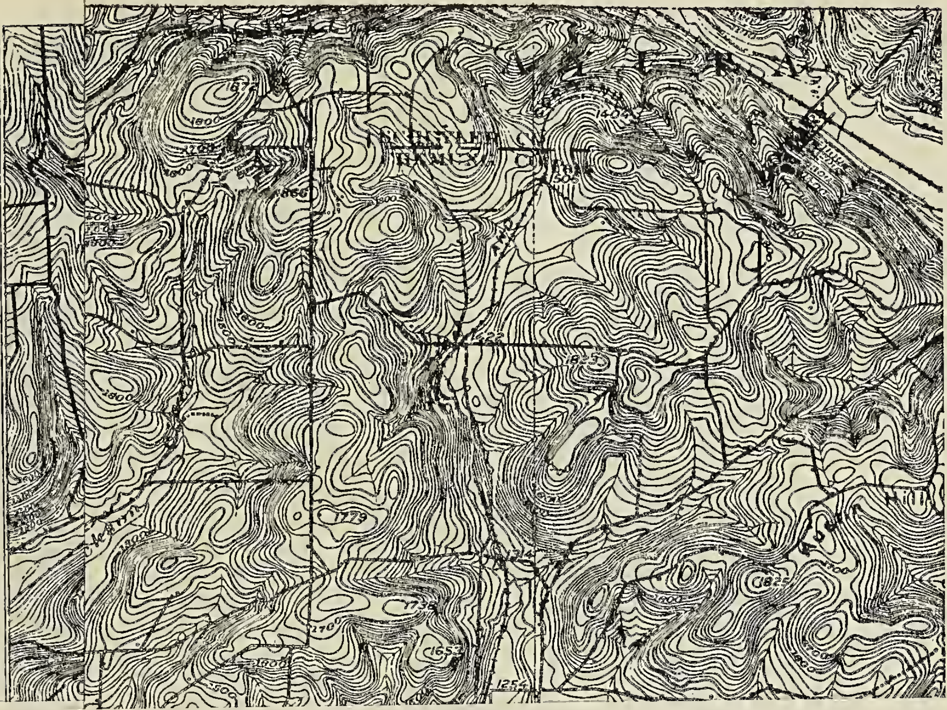
STA

BULLETIN 256 PLATE 10



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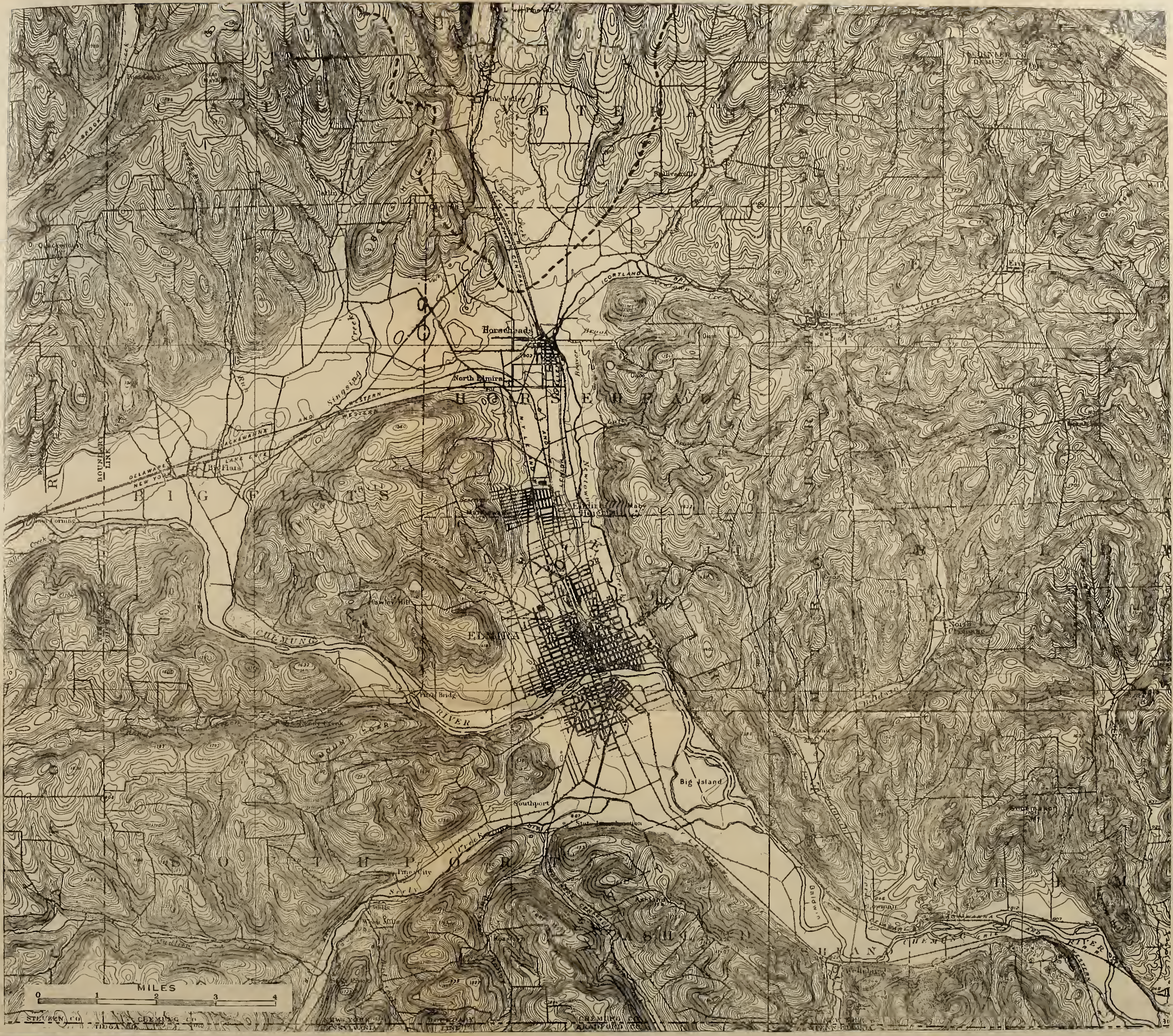
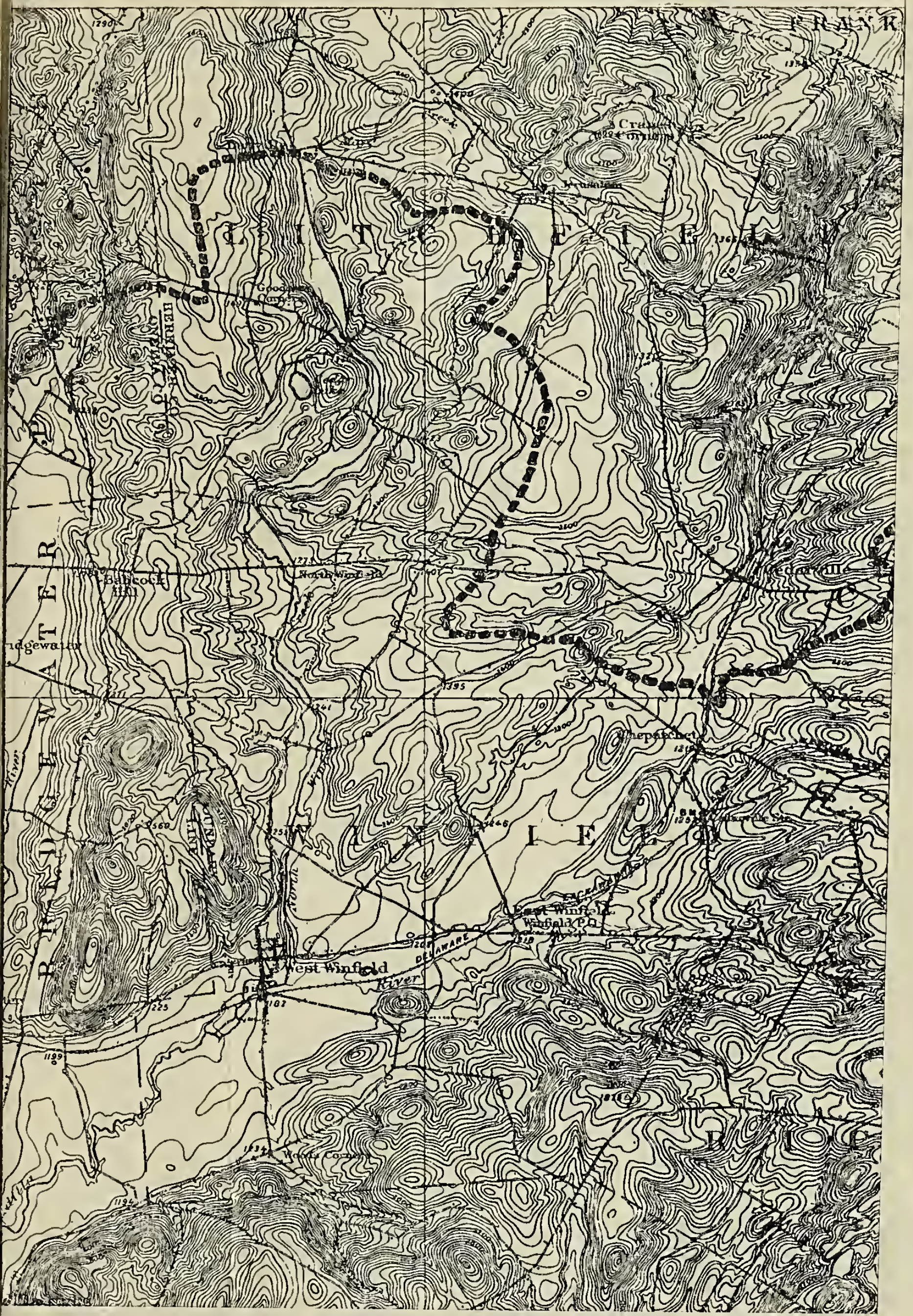
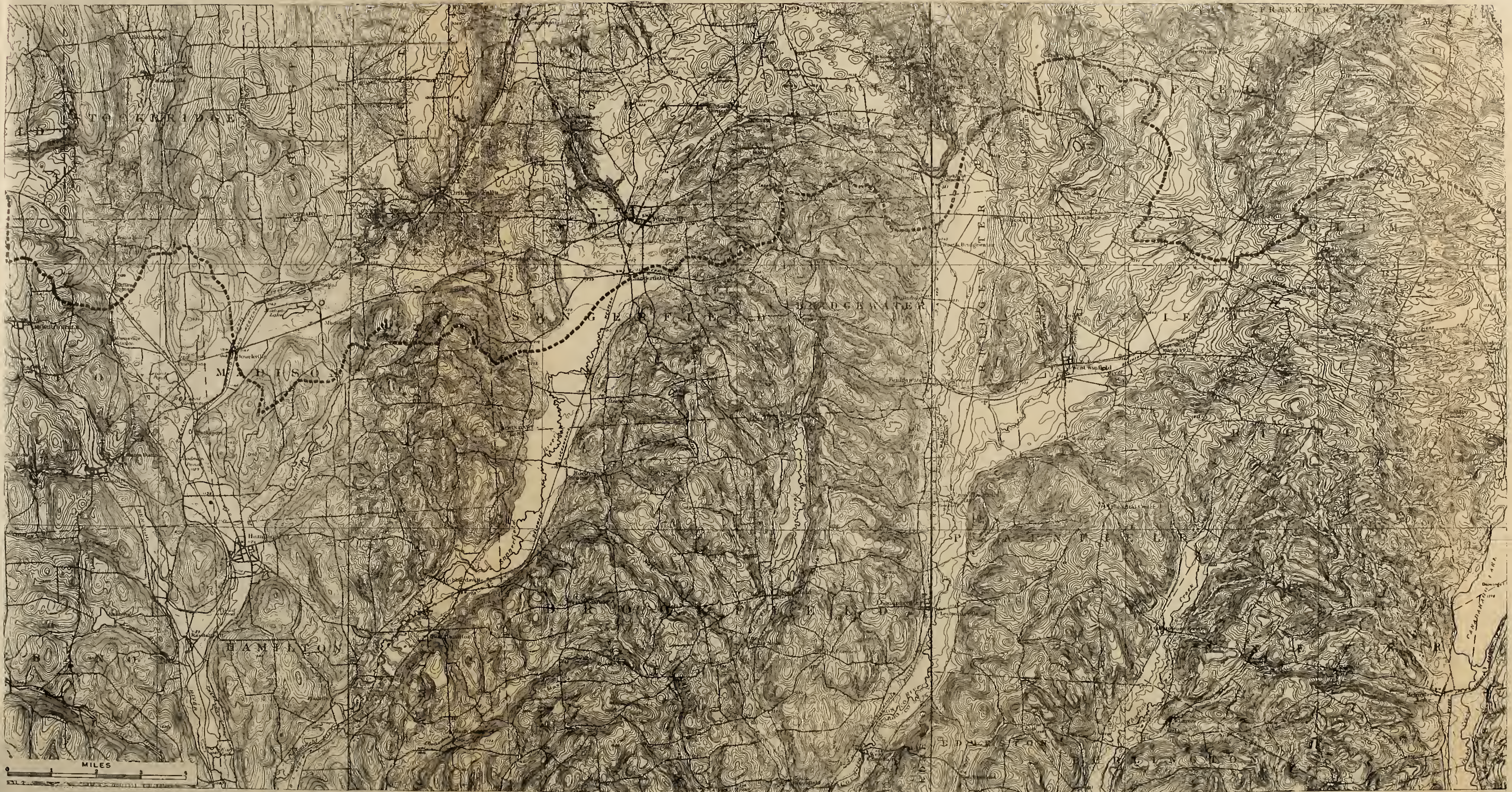


Elmira District

The broken line marks the divide between Ontario and Susquehanna drainage


FRANK
LITCHFIELD
BRIDGEWATER
WINFIELD
Babcock Hill
North Winfield
Cedarville
Chepachet
East Winfield
Winfield P.O.
West Winfield
Delaware River
Woods Corners
Bridgewater

22



Cols at the Heads of the Unadilla and Chenango Rivers

The broken line marks the present divide between northward and southward drainage

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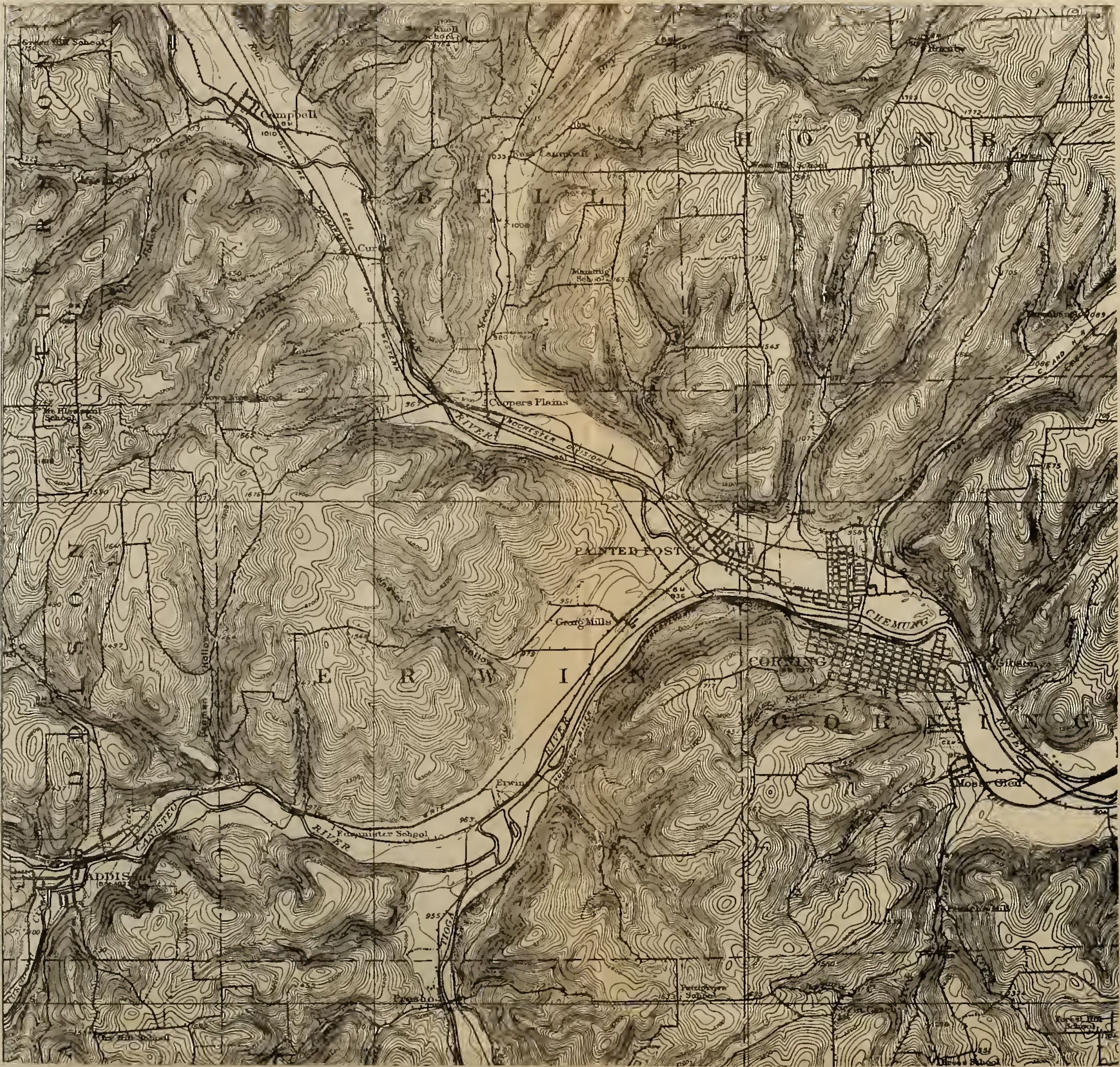
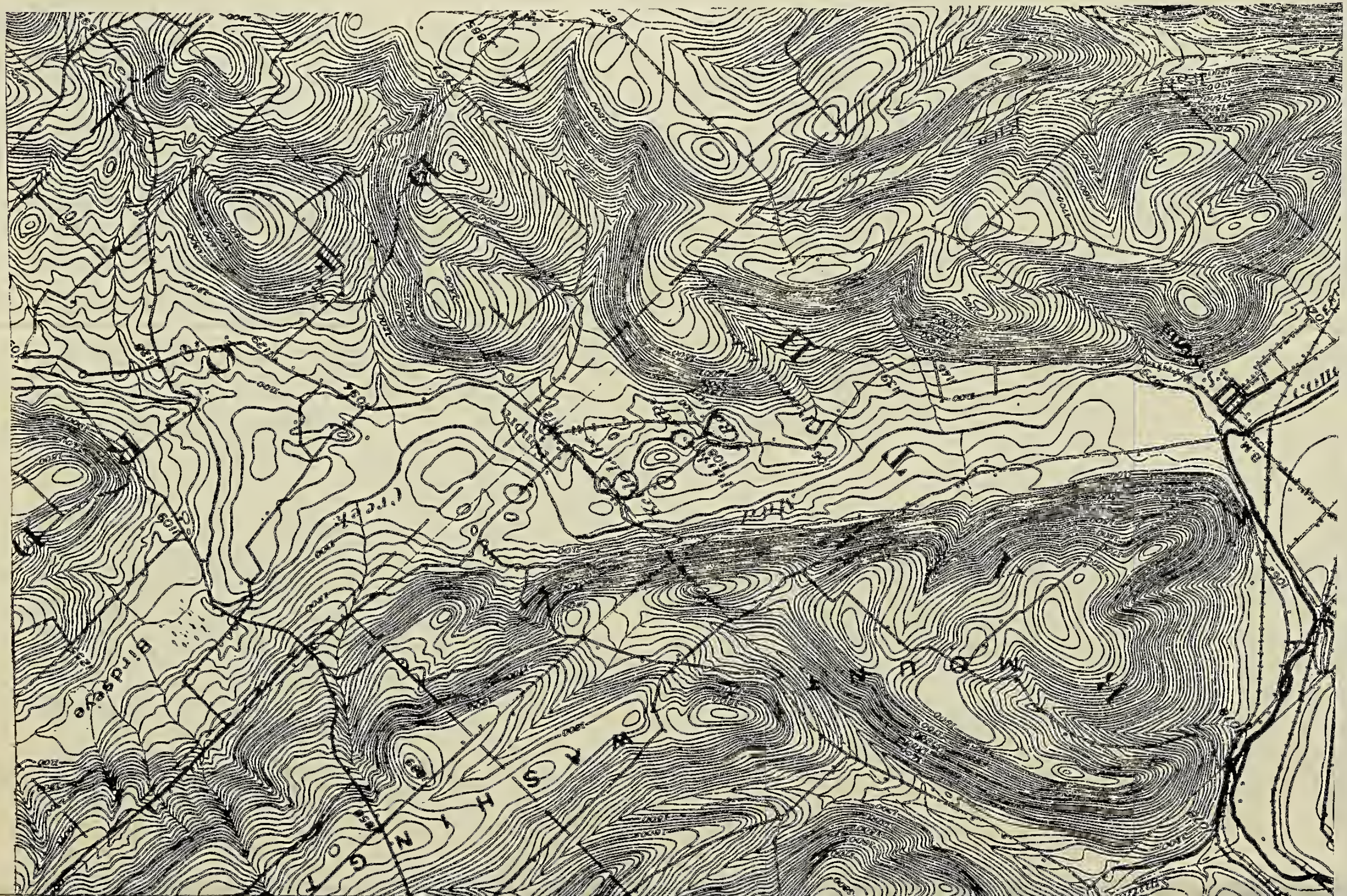
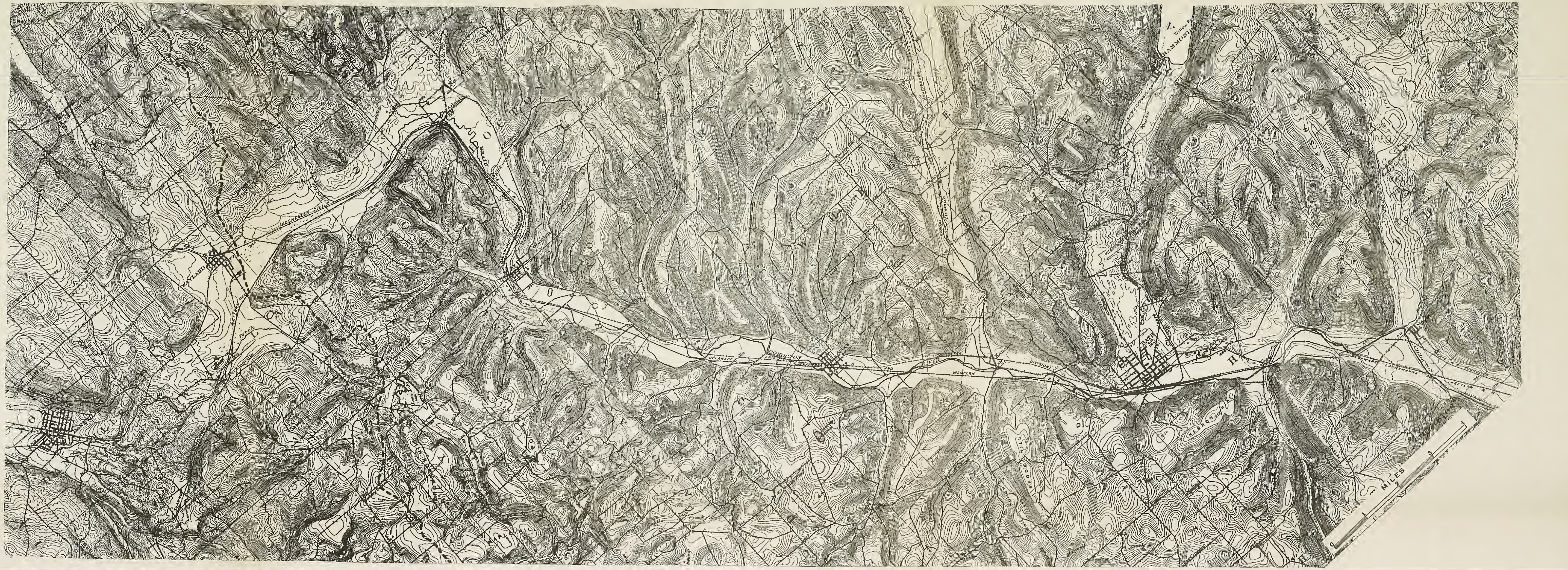
BULLETIN 256 PLATE 23



Corning District

BULLETIN 256 PLATE 24

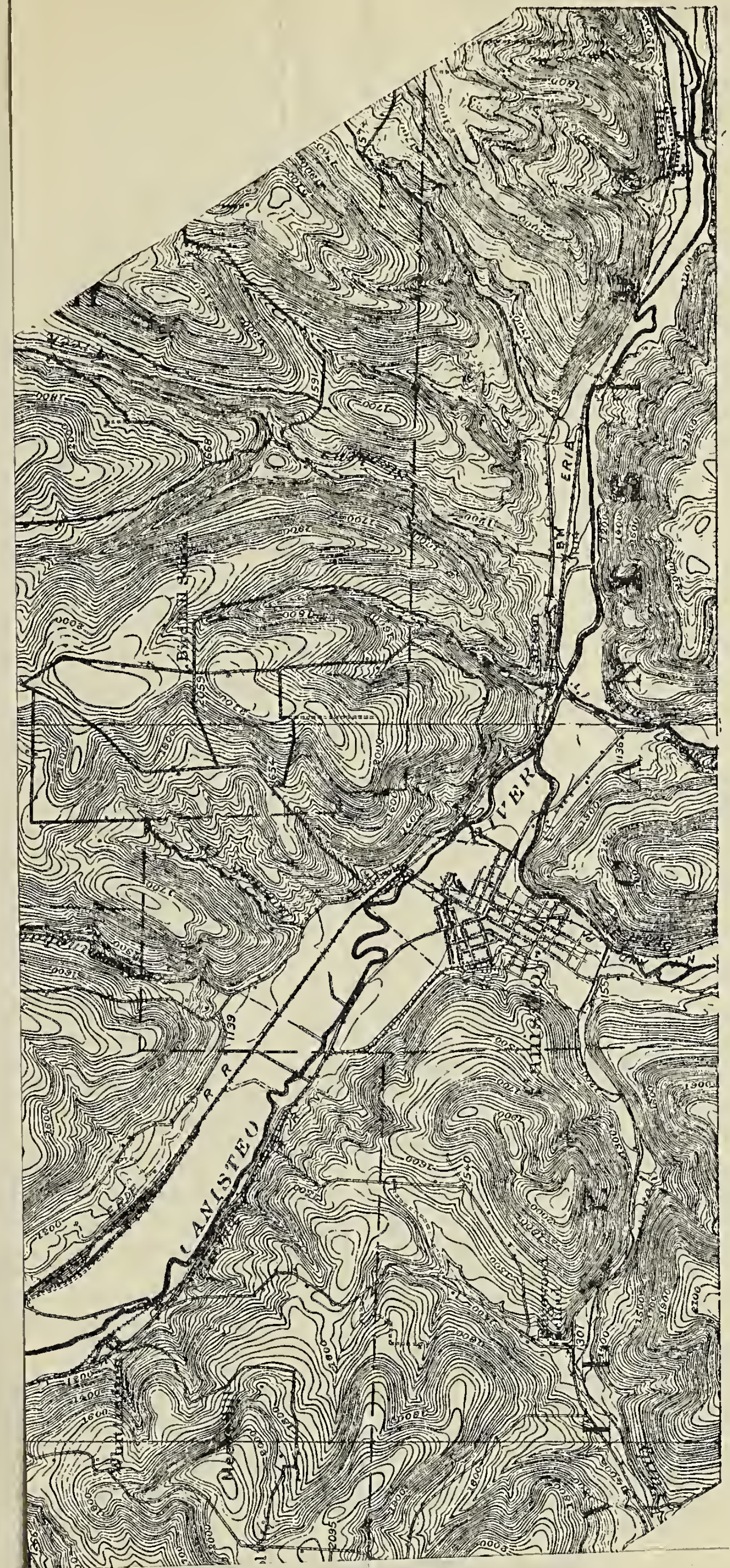


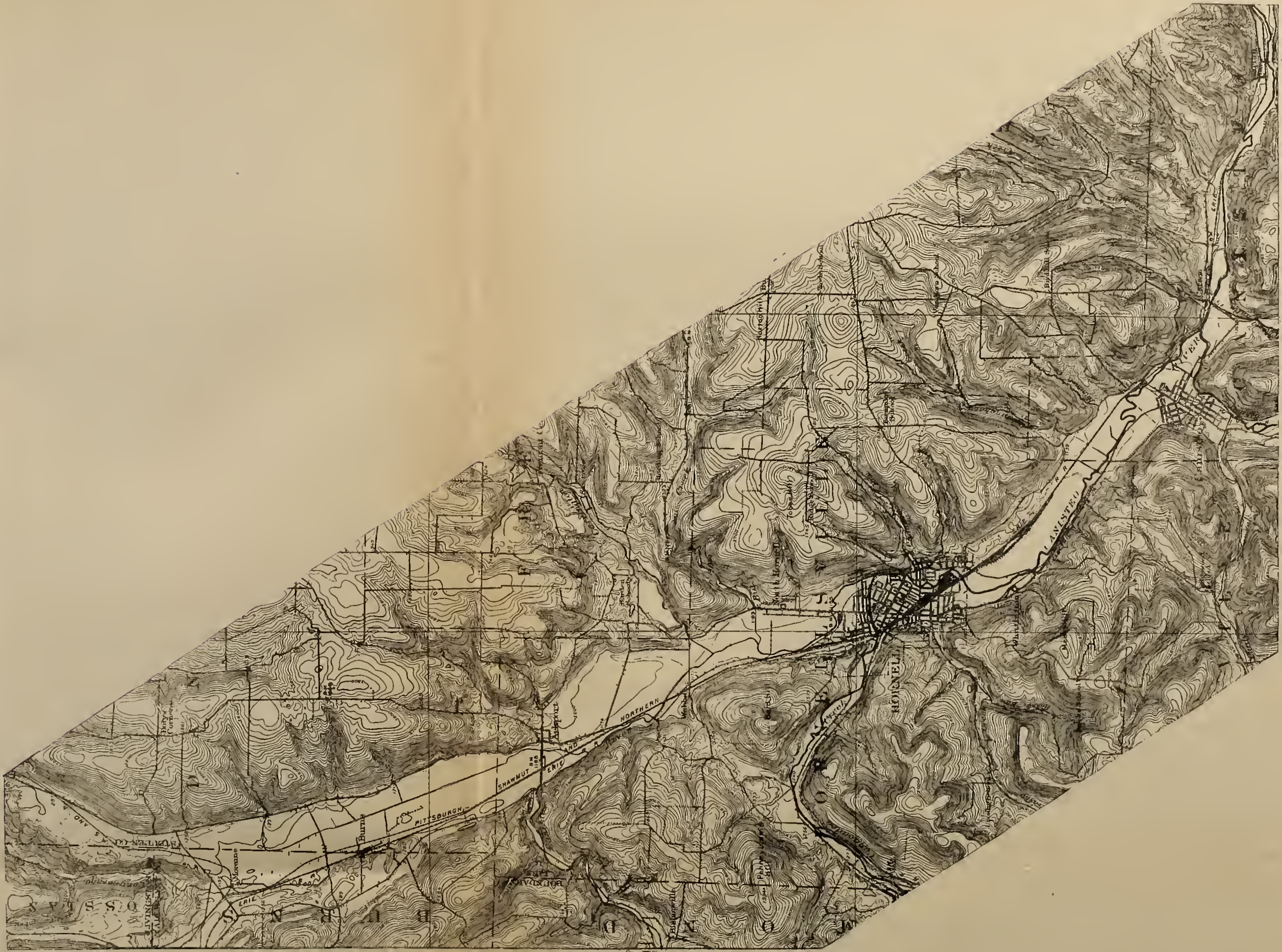


Cohocton Valley

The broken line marks the divide between Ontario and Susquehanna drainage

BULLETIN 256 PLATE 25





Hornell District; Upper Canisteo Valley

25-

New York State Museum Bulletin

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New York State Museum

JOHN M. CLARKE, *Director*

KEY TO GALL MIDGES

(A Resumé of Studies I–VII, Itonididae)

BY

EPHRAIM PORTER FELT

SMITHSONIAN INSTITUTION
MAY 8 - 1939
NATIONAL MUSEUM

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JOHN M. CLARKE, *Director*

KEY TO GALL MIDGES

(A Resumé of Studies I-VII, Itonididae)

BY

EPHRAIM PORTER FELT

INTRODUCTION

Technical descriptions and keys to genera are dull reading for the layman, even if there be hundreds of interesting facts interspersed. The study of gall midges, an exceedingly diversified and remarkable group, was begun in 1906. This bulletin presents the more striking and important facts concerning these insects from the economic, biologic and systematic aspects and through the key to genera and the extensive bibliography makes it relatively easy to look up the much scattered literature of a large group which has learned how to compel plants to provide both food and shelter. The index to parts I–VII will prove of great service to later students in facilitating reference to the hundreds of American species, many of which were described in the course of these studies.

Our knowledge of this group was very fragmentary in 1906. The present extensive classification has been worked out in close cooperation with the best European specialists, such as Kieffer, Rubsaamen and Tavares. There remains much to be learned concerning American gall midges, especially of their relation to plants, although it is believed that much of fundamental importance has been placed on record and the basis of an enduring classification established.

Several of the gall midges are of great economic importance, especially the Hessian fly, the wheat midge, the clover midge and the pear midge. Others, such as the sorghum midge, the grape midge, the chrysanthemum midge and the box midge, have attracted notice in more recent years. It is probable that others will be found to possess destructive tendencies and hence, although this study was perforce systematic to a large degree, it may have important economic applications.

A STUDY OF GALL MIDGES, VIII

The gall midges or gall gnats, Itonididae (better known as Cecidomyiidae) are well-known inhabitants of various plant deformities, although a considerable series do not produce galls upon plants, a number living upon dead vegetable matter and many being predaceous in habit.

These insects are small flies ranging in length from 8 to .5 mm or even less. The midges, although small and weak, are found in great variety, frequently in large numbers and in some instances are serious pests, such as the Hessian fly, the wheat midge and the chrysanthemum midge.

The American representatives of this family have been until recent years largely unknown. Our study of this group has resulted in the recognition of more than 100 North American genera, differentiated by marked peculiarities in structure and duly correlated with the approximately 400 known genera. We know at present about 900 American species, about 700 having been reared. This is by no means exhaustive since intensive collecting has been largely restricted to New York and New England, although considerable collecting and rearing has been done in various western states. There are now known in the world some 3000 species of Itonididae representing about 400 genera.

Definition. The gall midges may be defined as small Diptera with the tibiae unarmed apically, the coxae not produced and the wings usually with but three or four long veins and no crossveins. Extreme forms may have six or seven long veins and but one crossvein or as a result of reduction, the wings may be nearly veinless.

This family comprises small, slender flies usually with broad wings and relatively long antennae and legs. The head is small, the eyes are round or reniform, sometimes holoptic; the ocelli are present in the more generalized forms and wanting in the others. The antennae vary greatly in length, may have from six to forty-one segments, the flagellate segments being cylindric, subglobose, petiolate or binodose and frequently verticillate, especially in the male. The proboscis is normally short, although greatly produced in Clinorhyncha and less so in several other genera. The palpi are normally quadriarticulate, in certain genera triarticulate, or uniarticulate, and in Oligarces wanting. The thorax is ovate, more or less convex, without a transverse suture. The abdomen is normally composed of nine segments, the last bearing the genitalia. The ovipositor may be short, moderate in length or greatly produced, and in certain genera modified into a highly specialized, needle-like structure. The legs are long and slender; the coxae not very long; the tibiae without terminal spurs and the first segment of the tarsi very short, except in the more generalized forms; wings large, usually hairy, narrowed basally, without alulae. There are at most five and usually but three longitudinal veins, namely the first, the third and the fifth. The fourth is present in some of the more generalized forms, sometimes forked and frequently obsolescent. The sixth, if present, is usually a branch of the fifth, although distinct in generalized forms. A costal vein incloses the entire wing. The anterior crossvein, when present, is very near the base of the wing and incloses the one basal cell.

The gall midges are most closely related to the Mycetophilidae, being separated therefrom by the relatively short coxae, the absence of tibial spurs and the usually fewer wing veins. The Mycetophilidae live mostly upon fungus or decaying vegetable matter, a habit shared only by the more generalized Itonididae. The Culicidae with their aquatic larvae and rather numerous scaled wing veins are easily distinguished from the gall midges. The same is true of the minute Chironomidae with plumose antennae in the male, the well-developed, projecting-hoodlike thorax and the frequently aquatic, wormlike larvae. The small Psychodidae, with ovate wings having numerous hairy veins, are frequently captured with gall midges and are readily separated by the wing structure. Some of the larger Itonididae, such as species of Hormomyia, present a superficial resemblance to certain of the smaller crane flies or Tipulidae, a family easily distinguished by the V-shaped suture on the thorax and the several crossveins in connection with a characteristic venation and a very generally larger size.

The minute, plastic gall midges require little nourishment; they depend for sustenance largely upon living plant and animal tissues; and in certain groups they exhibit a high degree of specialization and dependence upon favored food plants or species belonging to natural botanical groups. Consequently, we find these tiny insects levying for food and shelter upon a large number of plants and occupying a position hardly touched by other insects and allied forms, aside from the gall wasps or Cynipidae and the gall mites or Eriophyidae. The closeness of this relationship and the adaptation of certain midge genera to plants is brought out in some detail in the discussion of food habits. The great plasticity in this group has resulted in the production of numerous genera and species.

Geographical distribution. The worldwide distribution of these fragile flies with their weak flight and the apodous or nearly apodous larvae is striking testimony to the efficiency of the natural agencies which have brought about this condition. These tiny insects, many closely dependent upon the development of certain plants or parts of plants, appear to exist in all portions of the world, since an examination of available records indicates representatives of the suborders and principal tribes at least in practically all the important faunal regions. The more primitive or dominant genera in these various groups such as Lestremia, Campylomyza, Porricondyla, Dasyneura, Oligotrophus, Asphondylia, Lasioptera, Contarinia and Lestodiplosis, are found on most of the continental areas. They are represented among living forms by numerous species, many of them capable of subsisting under comparatively simple conditions and therefore not easily exterminated or isolated by adverse climatic or physical changes.

It is noteworthy that of the seven genera known from the Baltic Amber, six are recorded also from Australia, three from New Zealand, and two from Africa, and in all probability more of these genera occur in other areas of the southern hemisphere. The African, Australian, New Zealand and South American faunae appear to contain a considerable number of ancient, highly specialized off-shoots from the somewhat primitive worldwide genera mentioned above, and their occurrence suggests a zoological isolation where only the more dominant would continue and where the natural tendency to variation would be consequently less subject to interference by closely related forms or species in the process of formation.

One of the striking peculiarities in distribution is the occurrence of the genus Aplonyx in the northern hemisphere, where it is known only from the Mediterranean region and the vicinity of Salt Lake, Utah, localities favored by both host plants and insects. Species of Didactylomyia, a very peculiar form, occur in both North America and India, while the closely related Erosomyia and Indodiplosis are occidental and oriental respectively.

There seem to be little or no data to suggest a connection between habits and a general distribution, since there does not appear to be a better representation of midges like Lestremia and Porricondyla breeding in decaying vegetable or woody tissues, materials which might easily drift to distant shelters, than there is of bud or leaf inhabiting forms which find temporary shelter in plants and transform in the soil, such as species of Dasyneura and Contarinia. This is also true of Lasioptera and Rhabdophaga, species passing most of their existence within plant tissues and therefore more likely to be carried great distances with the host plant. An equally wide distribution is true of predaceous midges with only a secondary relationship to plants, such as Aphidoletes, Mycodiplosis and Arthrocnodax.

There is a possibility of some forms being distributed by birds since records are available showing that birds feed upon the galls of Cincticornia and there appears to be no reason why those of Caryomyia might not be equally acceptable. This by no means explains the general distribution of numerous other forms living in thin-walled galls or even exposed upon the foliage. The investigations of McCulloch have shown that the Hessian Fly, one of the gall midges, may drift at least 2 miles with the wind, and taking into account the numerous records of other insects flying or drifting long distances with the wind, it seems very probable that air currents, mostly gentle ones, may have been very important factors in distributing these small forms over the earth.

The wide distribution of some of the more dominant forms is well shown by the following tabulation based largely upon continental areas:

ITONID GENERA OF PRESUMABLY WORLD-WIDE DISTRIBUTION

TRIBE AND GENUS	NORTH AMERICA	SOUTH AMERICA	EUROPE	ASIA	AFRICA	AUSTRALIA	NEW ZEALAND
Lestremiinariae							
Catocha Hald	x	.....	x	.....	.....	.....	.....
*a*Lestremia Macq	x	x	x	x	...	x	x
Campylomyzariae							
*a*Campylomyza Meign	x	...	x	...	...	x	x
*a*Joannisia Kieff	x	...	x	...	x[1]	...	....
Heteropezinae							
Oligarces Mein	x	...	x	...	...	...	....
b, *c*Johnsonomyia Felt	x	x	...	...	x	...	....
*a*Miastor Mein	x	...	x	...	...	x	x
Leptosyna Kieff	x	...	x	...	...	...	....
Brachyneura Rond	x	...	x	...	...	...	....
Spaniocera Winn	...	...	x	...	...	x	....
Porricondylariae							
Didactylomyia Felt	x	...	...	x	...	...	....
Holoneurus Kieff	x	...	x	...	...	...	....
*a*Colpodia Winn	x	...	x	x	...	x	....
Dirhiza H. Lw	x	...	x	...	...	...	....
Porricondyla Rond	x	x	x	...	x	x	x
Camptomyia Kieff	x	...	x	...	...	...	....
Rübsaamenia Kieff	x	x	x	x	...	...	....

ITONID GENERA OF PRESUMABLY WORLD-WIDE DISTRIBUTION
(*Continued*)

TRIBE AND GENUS	NORTH AMERICA	SOUTH AMERICA	EUROPE	ASIA	AFRICA	AUSTRALIA	NEW ZEALAND
Porricondylariae (*Con't'd*)							
*a*Asynapta H. Lw	x	...	x	x	...	x	....
Winnertzia Rond	x	...	x	...	...	x	....
Dasyneuriariae							
Cystiphora Kieff	x	...	x	...	...	...	....
Rhabdophaga Westw	x	...	x	...	...	...	....
Dasyneura Rond	x	x	x	x	x	x	....
Diarthronomyia Felt	x	...	x	...	...	...	....
Lasiopteryx Westw	x	...	x	...	...	...	....
Ctenodactylomyia Felt	x	...	...	x	...	...	....
Scheueria Kieff	...	x	...	x	...	...	....
Oligotrophiariae							
Rhopalomyia Rübs	x	x	x	x	x	...	....
Oligotrophus Latr	x	x	x	x	x	x	....
Janetiella Kieff	x	x	x	...	...	...	....
Phytophaga Rond	x	...	x	x	...	x	....
Asphondylariae							
Schizomyia Kieff	x	...	x	x	x	...	....
*b*Cincticornia Felt	x	...	x	...	...	x	....
Asphondylia H. Lw	x	x	x	x	x	x	....
Lasiopterariae							
Trotteria Kieff	x	...	x	...	...	...	....
*a*Lasioptera Meign	x	x	x	x	x	x	....
Aplonyx De Stef	x	...	x	...	...	...	....
Clinorhyncha H. Lw	x	...	x	...	...	...	....
Itonididinariae							
Toxomyia Felt	x	...	...	x	...	...	....
Contarinia Rond	x	...	x	x	...	x	....
Thecodiplosis Kieff	x	...	x	...	...	...	....
Dentifibula Felt	x	...	...	x	...	...	....
Dicrodiplosis Kieff	x	...	x	...	...	...	....
Bremia Rond	x	...	x	x	x[2]	...	....
Aphidoletes Kieff	x	...	x	...	...	x	....
Karschomyia Felt	x	x	...	...	...	...	....
Mycodiplosis Rübs	x	x[3]	x	x	...	...	....
Diadiplosis Felt	...	x	...	x	...	...	....
Arthrocnodax Rübs	x	x	x	x	...	...	....
Hormomyia H. Lw	x	...	x	x	...	...	....
Trishormomyia Kieff	x	...	x	x	...	...	....
Pseudhormomyia Kieff	x	...	x	x	...	...	....
Monarthropalpus Lab	x	...	x	...	...	...	....
Hyperdiplosis Felt	x	x[3]	...	...	...	...	....
Lestodiplosis Kieff	x	x	x	x	x	x	....
Itonida Meign	x	x	x	x	...	x	x
Parallelodiplosis Rübs	x	...	x	x	...	...	....
Cystodiplosis Kieff and Jorg	x	x	...	...	...	...	....

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a Recorded from the Baltic Amber of the Upper Eocene.
b Polystepha Kieff. and Eocincticornia Felt are included because of obvious affinities.
c Probably closely related to the Australian Chastomera Skuse.
[1] Seychelles.
[2] Record based on related Heterobremia Felt.
[3] St Vincent.

Economic importance. The plant infesting habits of many gall midges make those species living in the seeds of injurious or undesirable plants of direct economic importance because they assist materially in checking such growths. The prickly pears or Opuntias are pests of agricultural lands in various sections of the world and in our southwest are seriously affected and to a certain extent controlled by gall midges. One species, Itonida opuntiae Felt, was brought to notice because of its abundance in the cactus collection of the New York Botanical gardens and while it was injurious there, such a development would be regarded as beneficial in an area where these plants are undesirable. Another species, Asphondylia opuntiae Felt, is so abundant as to ruin practically every cactus fruit in large areas in sections of California. A very different species of gall midge, Dasyneura gibsoni Felt, has been reared from flower heads of Canada thistle in such large numbers that it is regarded as of material service in checking the thistle, and in some parts of Indiana, it appears to have almost completely destroyed the weed. Additional knowledge of the group would doubtless permit the recognition of a number of other species which are beneficial because of their checking the growth of undesirable plants.

There is a rather large number of gall midges which prey upon other midges or small insects, such as aphids, or live at the expense of the minute gall mites, and are therefore beneficial. Ordinarily gall midges preying upon others are not particularly serviceable, though such appears to be the case with a number of species attacking aphids or plant lice. The total number of species of gall midges possessing these desirable habits must be considerable since a number of genera are known to be predaceous.

Gall midges are much better known through the work of injurious species, such as the Hessian Fly, Phytophaga destructor Say, a species which first attracted attention in this country about 1779. It was very injurious in the latter part of the eighteenth century to wheat grown on Long Island, and in the middle of the last century it occasioned losses in this State running as high as 500,000 bushels of wheat. More recent depredations occurred in 1901, at which time the loss in New York State alone was placed at $3,000,000.

The wheat midge, Cecidomyia tritici Authors or Thecodiplosis mosellana Gehin, is another notorious offender, though losses in recent years have been comparatively limited. It was credited in 1854 with reducing the crop in New

York State by about 7,000,000 bushels, an estimated loss of $15,000,000, and the depredations in Ohio were nearly as serious. A recurrence of injury, though not nearly so extensive, obtained in 1917, 1918 and 1919, the rye fields of Albany, Columbia and Rensselaer Counties being somewhat generally infested. The insect also caused a considerable reduction of the wheat crop in western New York.

The pear midge, Contarinia pyrivora Riley, a European species, first recognized in this country about 1877, has been locally injurious in important fruit sections of New York and New England.

The clover midge, Dasyneura leguminicola Lintn., was so abundant in New York State about the middle of the last century as almost to prevent the growing of clover seed.

The violet gall midge, Phytophaga violicola Coq., is a recent pest which has become well established in the important violet growing centers in and about Rhinebeck. It has inflicted serious losses upon growers.

The rose midge, Dasyneura rhodophaga Coq., has been very injurious locally in New York State and in other parts of the country.

The chrysanthemum midge, Diarthronomyia hyopgea Lw., a very recent introduction, has become established in greenhouses in the United States and Canada and has caused serious losses.

The grape blossom midge, Contarinia johnsoni Sling., is widely distributed in the Chautauqua grape region, causing occasionally severe injury to early Moore grapes and many irregular bunches in the commercially important Concord grape.

The grape tomato gall, Lasioptera vitis O. S., produces deformations on the leaves and tendrils and deserves mention because of the apprehension it causes.

The cranberry gall midge, Dasyneura vaccinii Smith, causes many dead cranberry tips and is a species which is responsible for considerable injury on some bogs.

The European willow gall midge, Rhabdophaga salicis Schrk., another recently introduced species, is important in sections where basket willows are grown, since the galls make the canes brittle and therefore practically valueless.

The linden twig gall midge, Cecidomyia citrina O. S.,[1] occasionally becomes very abundant and seriously stunts the growth of this valued shade tree by destroying the buds and reducing the vitality of the slender twigs, the latter due to the interrupted circulation resulting from the deformed woody tissues.

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[1] Possibly identical with the European Contarinia tiliarum Kieff.

The catalpa midge, Itonida catalpae Comst., infests the blossoms and young leaves of catalpas, destroys the growing tips and produces stunted, comparatively valueless trees.

The box elder gall midge, Cecidomyia negundinis Gill., has been reported as decidedly injurious to box elder trees at Ames, Iowa.

The tulip gall fly, Thecodiplosis liriodendri O. S., produces a very characteristic blister on the leaf, and in the South at least appears to be decidedly injurious to its host.

The sorghum midge, Contarinia sorghicola Coq., has become so abundant in certain sections of the South as to prevent the growing of sorghum seed. An allied form, Contarinia gossypii Felt, is a serious enemy of cotton in the British West Indies and later may compel attention from southern planters.

The box midge, Monarthropalpus buxi Lab., has been introduced recently and has already shown itself to be moderately injurious to this highly-prized ornamental shrub.

Besides the species discussed above, there are a number of European midges which may at any time become established in this country and under favorable conditions prove of considerable economic importance. Professor Fred V. Theobald records a leaf-curling pear midge under the name of Diplosis pyri Bouché, a species of Dasyneura. He has also discovered a previously unknown injury to Swede turnips by Contarinia nasturtii Kieff., a deformation of the basal portion of the leaf stalk at first supposed to be the work of the cabbage root fly (Phorbia brassicae). A third enemy is known as the strig maggot, Diplosis humuli, the larvae occur in the bracts of hop aments and appear to be capable of inflicting serious injury. All three of these, as well as a number of other midges, could be easily introduced and might, under our new world condition, cause serious losses.

It is well known that this family of small flies comprises a large series of species living at the expense of various parts of a great many different plants, some of these occurring upon plants of little or no economic importance may in time change their habits and become destructive pests.

Material studied. A very considerable proportion of the material studied was collected or reared from galls taken in New York State, mostly in the vicinity of Albany. A large number of species was secured by systematic collecting during 1906 by members of the office staff, D. B. Young, Assistant State Entomologist, being particularly successful. This did much toward disclosing the richness of the fauna and resulted in securing species which may not be reared for many years. It was an excellent preliminary to numerous successful rearings and the consequent great additions to our knowledge of the biology and ecology of the group.

Through the courtesy of Dr L. O. Howard, chief of the Bureau of Entomology, United States Department of Agriculture, we were able to study the material in the National Museum, which is exceptionally rich in reared species and contains the types of most of the species described by the late D. W. Coquillett. The collections in the Museum of Comparative Zoology, Cambridge, Mass., also rich in types or cotypes of species described by earlier workers, were studied with the kind permission of Samuel Henshaw. William Beutenmueller of the American Museum of Natural History, allowed us to study his collections and generously placed at our disposal, types of several of his species. Professor T. D. A. Cockerell of the University of Colorado, Boulder, Colo., with commendable liberality, donated to the State Museum the types of several species described by him, and also contributed galls and new species collected in that comparatively unexplored section. Professor E. Bethel of Denver, Colo., has favored us through a series of years with many very desirable galls from which a number of interesting species have been reared. The late Dr James Fletcher, formerly Government Entomologist of Canada, personally and through correspondents, supplied us with some valuable material, a work supplemented by collections from Professor T. D. Jarvis of the Ontario Agricultural College. C. W. Johnson of the Boston Society of Natural History generously placed his material, collected with rare discrimination, at our disposal. The late Dr M. T. Thompson of Clark University, Worcester, Mass., lent valuable specimens and photographs and contributed data relating to forms of that section. The late Miss Cora H. Clarke of Boston and Magnolia, Mass., a very enthusiastic collector, sent us numerous notes, photographs and galls, the last named producing an unusual number of very interesting forms. L. H. Weld of Evanston, Ill., donated several galls from which undescribed species were reared. The same is true of Professor James G. Needham of Cornell University, who placed at our disposal somewhat extensive material taken at Lake Forest, Ill. The late E. S. Tucker submitted for study several interesting species from Kansas and Texas, and the late L. H. Joutel favored us with several species collected in the vicinity of New York City. C. P. Alexander, now of the Massachusetts Agricultural College, placed at our disposal a number of unique forms, mostly from New York State. Winthrop Packard of Canton, Mass., supplied us with willow twigs which produced Sackenomyia packardi Felt. Several remarkable species were reared from material collected by Professor H. R. Hagan of Utah. An exceptionally fine series of western galls and reared midges was received from P. H. Timberlake, now of the Hawaiian Sugar Planters Experiment Station at Honolulu.

Numerous collections of insect galls have been received from various parts of the country, notably Roy Latham, Orient, Mrs E. P. Gardner, Canandaigua, and James R. Wier, then of the state of Washington.

The value of the taxonomic work in this group was greatly increased by an opportunity of examining many of the generic types in European museums. Through the kindness of Professor E. E. Austen of the British Museum of Natural History, we were allowed to study the Stephens collection containing the Westwood types, which, though small in numbers, was exceptionally rich in generic types and is almost invaluable to the systematic student. Through the courtesy of Professor E. B. Poulton of the University of Oxford we had the pleasure of examining representatives of one or two American species described by Dr Asa Fitch and sent by him many years ago to Westwood. The kindness of Professor E. L. Bouvier made possible a study of Meigen's types in the Museum of Natural History at Paris. Professor Walter Voigt of the University of Bonn, Germany, placed at our disposal every facility for the study of the well-preserved and exceedingly valuable Winnertz collection in his custody. Dr K. Grunberg of the Natural History Museum of Berlin, Germany, assisted materially in our examination of the generic types in that institution.

Our acquaintance with the recently established genera, erected for the most part by Messrs Kieffer and Rübsaamen, has been greatly facilitated by the hearty cooperation of these gentlemen. Professor J. J. Kieffer permitted us in 1909 to examine his large collection at Bitsch, Germany, and generously donated to the Museum an excellent series of many of his generic types. These are a part of the State Museum collections. They have been mounted in balsam and are accessible to other students. The late Professor E. H. Rübsaamen of Berlin, Germany, kindly allowed us to examine many of his unpublished sketches and has contributed to the Museum authentic specimens representing a number of his new genera. We were able to secure through Professor Mario Bezzi of Torino, Italy, several generic types not obtainable elsewhere, and also a small collection of European galls.

The author has also been privileged to study considerable series of reared material from the Philippine Islands, Java, India and small collections from Africa, Australia and South America, all of value in taxonomic work.

We are under deep obligations to C. T. Brues, Bussey Institution, Forest Hills, Mass., who kindly determined many of the extensive rearings of parasites.

Methods. Recently collected or reared material was invariably described in a fresh condition and the anatomical details were supplied from microscopic mounts. The midges were mounted even if the specimen was unique, otherwise it is impossible to make out the characters satisfactorily. In the earlier work, one wing was usually mounted dry. This is rarely done now because it is difficult to dry the wings thoroughly and thus prevent deterioration of the preparation. The insect was cleared by boiling in a 5 per cent solution of potassium hydrate, the action being continued till the denser parts of the chitin were nearly transparent. The action should not be carried so far as to make the antennal structures too transparent. Dehydration with alcohol, the replacing of this with xylol and the latter in turn with balsam, followed the course ordinarily practiced in laboratories. The head was dissected or turned so that the palpi and antennae could be easily seen; the legs were straightened as far as possible and the genitalia laid out flat. This arrangement of the head and genitalia is considered necessary to a satisfactory interpretation of the structural characters. Larvae were mounted in nearly the same way, though without dissection, except that in the case of the larger species at least, it was frequently necessary to remove the body contents in large measure by manipulation with a needle. Many of our earlier mounts were made by John R. Gillett and the latter ones by Fanny T. Hartman and D. B. Young. We have found it entirely practical to put into balsam specimens which have stood for years on pins. Microscopic mounts are more permanent and desirable than the fragile insects attached to pin points.

Rearing has been confined almost entirely to obtaining adults from nearly full grown larvae. This is comparatively easy in the case of forms inhabiting herbaceous stems since it is only necessary to collect the galls in the late fall or preferably early spring and give them a moderate amount of moisture under approximately normal temperature conditions. It is more difficult with forms inhabiting subcortical galls on woody trees or shrubs (aside from many willow species) since the larvae do not mature until into June and it is necessary to defer the collecting of the galls until about that time. Species wintering in hard leaf galls, such as Caryomyia and Cincticornia, can be reared in the same way as those affecting stems, mentioned above. Inhabitants of willow stems or the conspicuous rosette galls are more easily obtained from material collected in the spring. The most difficult midges to rear are those occurring in soft leaf and bud galls and which normally hibernate in the earth, since they do not winter well. We have secured the best results by putting such galls in an ordinary fruit jar containing clean sand or, better still, soil or leaf mold, though the latter, unless sterilized, is apt to contain unknown species and thus produce confusion in the records. We have not been nearly so successful in rearing midges from sterilized leaf mold as from that which has not been so treated or from clean sand. The jars are kept moderately moist through the remainder of the growing season and in the fall transferred to a large box and partially surrounded with rather damp leaves to keep the insects at an approximately even temperature and protect them from excessive drying.

Synonymy. It is with the greatest reluctance that we have abandoned Cecidomyia Meign., substituting therefor Itonida Meign.[1] This step has been taken because it was felt that the International Code of Zoological Nomenclature would justify no other positio since the genus Itonida was accompanied by a very characteristic description, even though no species was designated by name. Three years later Cecidomyia, with practically an identical definition, was proposed by the same author and in addition Tipula pini was named as belonging thereto. There was for years a disagreement as to the type of this genus, and subsequently Loew proposed the generic name Diplosis. It is only within comparatively few years that this latter genus has been generally recognized as a synonym of Cecidomyia and that this designation in turn has been widely employed in a fairly concise sense. It is certainly to be hoped that this change, deplorable though it may appear at first sight, will be generally accepted, since there will then be no excuse for prolonged arguments in regard to synonymy. The provisions of the International Code are so explicit respecting this case that there is little ground for a misunderstanding.

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[1] 1908, Hendel, F. Verhl. k. k. zool.-bot. Ges. Wien, 58:49.
1908, Aldrich, J. M., Can. Ent. 40:370-373.
1908, Coquillett, D. W., Can. Ent. 40:457.
1909, Hendel, F., Wien. Ent. Zeit, 18:33-36

We have used Cecidomyia in this study as a group name to be applied to galls, the makers of which are unknown, or to species belonging in this family but which, for some reason, can not be referred to the more exactly defined genera.

Fossil forms. Such minute, fragile forms would hardly be found preserved in any numbers in ordinary strata. The Baltic Amber of the upper eocene contains a most interesting fauna as worked out by Meunier. A most significant feature is the almost total restriction of the species found in this deposit to the Lestremiinae, Heteropezinae and the most generalized tribe, Porricondylariae, of the Itonididinae. The Lestremiinae is represented by some ten species and four genera, these latter all persisting at the present time. Species of both the Lestremiinariae and the Campylomyzariae occur, such a relatively highly specialized form as Monardia being found. The ancient character of the Heteropezinae is well supported by the finding in Amber some eleven species referable to seven genera, belonging to this subfamily, only three of the genera being represented in our present fauna. By far the larger number of species, twenty-eight, representing ten genera, belong to the Porricondylariae, all but one persisting to the present day. The above forms, so far as known, live upon decaying or dead vegetable matter, and it is therefore natural to expect such species to be abundant before the more highly specialized groups appear.

Neostenoptera, belonging to the Heteropezinae and peculiar because of the narrow, long fringed wings having but one long vein, which latter unites with the anterior margin near the basal third, and also remarkable because of the antennal structure apparently similar to that of the synthetic Johnsonomyia Felt, has been recorded from the Copal of Africa.

In addition, a species of Lasioptera and two of Cecidomyia have been recorded from Amber. The tertiary oligocene beds of the White river have yielded two genera; Lithomyza, which probably belongs to the Lestremiinae, and another form provisionally referred to Lasioptera. These two were associated with such highly specialized insects as an Ichneumon and nearer allies like Corethra, Chironomus, Mycetophila, Sackenia and even several species of Musca. The Pleistocene[1] swamp deposits of Maryland contain swellings upon the leaves of bald cypress produced, in the opinion of Doctor Howard, by a gall midge.

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[1] 1906, Hollick, Arthur. Md. Geol. Surv. Pliocene and Pleistocene, p. 237.

MIDGE GALLS

The various excrescences and abnormal growths upon plants, caused by insects, are known as plant galls. They may occur upon all parts of a plant and may be produced by insects belonging to widely separated groups or orders, namely, the four-winged flies or Hymenoptera, the beetles or Coleoptera, the butterflies and moths or Lepidoptera, the two-winged flies or Diptera and the true bugs or Hemiptera. There are in addition to the above, certain gall mites (Eriophyidae) which produce many characteristic growths upon a large variety of plants. Several families in an order may produce plant galls as, for example, among the true flies or Diptera, the Trypetidae and Itonididae. It is proposed in this account to confine the discussion entirely to the deformities produced by the latter.

It is usually not difficult to recognize midge galls since the more specialized are almost invariably tightly closed and in every instance inhabited by a maggot which, as a rule, is easily differentiated from all other organisms likely to occur in such places, by the peculiar breastbone, a structure rarely absent. Even when this latter is rudimentary or wanting, the generally narrowly oval or lanceolate form of the whitish or yellowish maggot enables one to determine the group to which it should be referred. We do not recall a whitish or yellowish Itonid larva having a length over 2 mm and not possessing a distinct breastbone. After a little experience it is very easy to recognize the relatively stouter, white maggots of the Trypetidae, especially as these latter never have a breastbone. It is not difficult to distinguish between the Itonid maggot and the larvae of Cynipids or Tenthredinids, while Coleopterous grubs and Lepidopterous larvae have well-marked peculiarities. The galls produced by Hemiptera are easily recognized by the distinct orifice and the character of the inhabitants. The same is true of mite galls, although owing to the extremely small size of the producers, the minute, usually hairy openings are not so readily seen.

There are a number of galls produced by the Cynipidae or gall wasps which are commercially valuable, mostly because they contain tannic acid, although a few are edible. Little of this character appears to be known concerning midge galls, although the grape apple caused by Schizomyia pomum Walsh and Riley, is credited with possessing a pleasant, subacid flavor when young and succulent. Certain leaf galls on oak produced by species of Cincticornia are eaten by birds. It is probable that they also feed to some extent upon the galls of Caryomyia on hickory and very likely upon the galls produced by a number of gall midges.

A plant gall may be described as an excrescence produced directly or indirectly by an insect or other organism. It is by no means so easy to draw the line between what may be termed a gall and the minor deformities which can hardly be included in this category such, for example, as a slightly discolored area on a leaf accompanied by a very little or no swelling. In the interests of simplicity, we will not attempt to draw a line between what may be termed a plant gall and malformations unworthy of such classification. It is very convenient to discuss these deformations under various heads according to the portion of the plant affected, though it is recognized that the galls produced by some species may occur upon different portions of the plant and in not a few cases the primary infestation occurs in the bud.

Fruit galls (52 known). Using this term in the botanical sense, we would apply the designation not only to deformed fruit in the ordinary acceptation of the word, but also to affected seeds. Certain species, such as Dasyneura canadensis Felt and Oligotrophus betulae Winn., live in the seeds of spruce and birch respectively, producing only slight deformations. Contarinia pyrivora Riley inhabits the carpel cavities of the pear, destroying the seeds and producing a characteristic malformation of the fruit. Contarinia virginianiae Felt develops in the swollen fruit of the chokecherry, Prunus virginiana; the genus displays a marked partiality for seeds. Dasyneura grossulariae Fitch appears to cause but little deformity and produces a premature ripening of the gooseberry.

Bud galls. These deformations, some 198 in number, may vary from comparatively simple, arrested blossom or leaf buds to the highly complex, nutlike, multilocular gall produced by Schizomyia pomum Walsh and Riley. Blossom bud galls are usually slightly enlarged and more or less discolored. This is very well seen in the gall on grape produced by Contarinia johnsoni Sling., and also in the enlarged blossom bud gall on trumpet weed, produced by Dasyneura purpurea Felt. The leaf bud galls may be comparatively simple as in certain Compositae, or form compound heads such as those of Rhopalomyia capitata Felt on solidago. An extreme type of bud gall is seen in the pine cone gall on willow, produced by Rhabdophaga strobiloides Walsh. This gall also provides sustenance for a number of inquilines. Another gall not recognized as a bud gall although really so, is that produced by Rhabdophaga triticoides Walsh. This peculiar deformation of the twig is due to the parent insect depositing eggs and the larvae hatching therefrom developing in or near a number of adjacent buds, stunting the development of the shoot and producing the typical grain-head like appearance. The genus Asphondylia and many species of Rhopalomyia and Dasyneura display a marked preference for bud galls.

Leaf galls. Under this category we find a large number, 255, of extremely varied deformations. The simplest type is perhaps a marginal leaf roll, such as that produced by a species of Itonida on poplar leaves, or a more specialized type like that of Itonida foliora Hkr. on oak foliage. These leaf folds may be rather loose or comparatively tight, and in one instance, namely Mycodiplosis cerasifolia Felt, the cherry leaf was folded longitudinally along the midrib, the young maggots developing here and there between the apposed surfaces and producing distinct thickenings. Vein folds, including those along the midrib, present considerable variation from the simple vein fold of Cecidomyia pudibunda O. S. on Carpinus to the large, tumid, midrib thickening on ash, produced by Contarinia canadensis Felt, or the less marked thickening on oak foliage with its conspicuous, white pile characteristic of Cecidomyia niveipila O. S. These vein enlargements may be discolored and limited to a rather definite position, as in the case of Sackenomyia viburnifolia Felt, or they may coalesce with irregular, tumid enlargements of adjacent tissues to produce the typical Lasioptera vitis gall on the leaf or even the tendril of the grape. This latter type of gall may afford sustenance for midges belonging to several genera.

There are in addition to the above characterized leaf galls, a number which are rarely or never associated with the veins. One of the simplest type is an oval or circular, pustulate enlargement such as that produced on oak leaves by Cincticornia simpla Felt, or the similar though somewhat more marked swelling occurring on aster leaves and referable to Asteromyia vesiculosa Felt. The special type of blister gall produced by the genus Asteromyia on aster and solidago, in particular, is worthy of mention. These galls are slight thickenings of the leaf tissues inhabited by one or several larvae, the interior frequently being partly filled with a carbonaceous material which, in the case of Asteromyia carbonifera Felt, is so abundant as to give a characteristic black color to both surfaces of the gall. A number of these galls have been distributed among botanists as species of Rhytisma. The gall of Itonida anthici Felt has also been attributed to fungus (see below).

The genus Cincticornia affords excellent examples of progressive development in leaf galls, since that produced by Cincticornia americana Felt is a mere pustule while that of C. globosa Felt is subhemispherical and intermediate in character between the simple, pustulate gall and the compound, polythalamous one produced by Cincticornia pilulae Walsh. Similar leaf galls occur on Carya in the leaf tissues between the veins and present great diversities in form, ranging from a comparatively simple, blisterlike structure to complex, globular or conical deformations.

Stem galls (173 known). We use this designation for both stem galls in the literal sense of the word and also for those deformities occurring upon branches, since the latter differ from the former only in location. Stem galls may be classed as medullary and subcortical. The medullary galls occur mostly in herbaceous vegetation and the smaller limbs or shoots of shrubs or trees. These galls may be inhabited by one or more larvae, the latter usually forming a more or less definite channel along the pith, as Neolasioptera ramuscula Beutm. or Lasioptera humulicaulis Felt. The presence of the insect is usually indicated by a distinct enlargement; occasionally the stem may be channeled irregularly, a type of work well illustrated by that of Neolasioptera hibisci Felt, in the variably swollen stems of Hibiscus moscheutos.

The subcortical type of gall is rather common in herbaceous plants and is the predominant stem gall in woody plants. It is usually polythalamous, frequently eccentric as in the case of Lasioptera solidaginis O. S. or Neolasioptera sambuci Felt. Occasionally these inhabitants of supposedly typical subcortical galls tunnel the wood largely, as appears to be true of Rhabdophaga cornuta Walsh. The form and size of the subcortical galls appear to be determined largely by the number of eggs deposited within a given area. They may be relatively small and contain only one or two larvae, or very large and irregular and inhabited by twenty-five to possibly fifty larvae.

Root galls. Only a few species, six, are known to produce galls upon roots, probably because of the great difficulty attendant upon their detection. There appears to be no marked difference between the root and the stem galls, and we are therefore content simply to call attention to the similarity existing between the two.

Fungi and gall midges. A considerable series of midges, representing a number of genera, live wholly or to a large extent upon or in fungi. It is very probable that the larvae of many species of Mycodiplosis Rübs. live exposed upon fungus growths and feed upon the spores. The same is true of Hyperdiplosis Felt and at least two species of Toxomyia Felt. Other midge larvae occur in fungus affected wood, as for example those of Lasiopteryx flavotibialis Felt and Monardia lignivora Felt. It is quite probable that a number of the more generalized gall midges have habits similar to the last two species mentioned. Similar conditions may also be found in the European fauna and presumably in those of other parts of the world.

A most interesting condition is found among certain blister leaf galls occurring commonly upon Solidago and aster, because they simulate in a general way the appearance of fungi so closely that for years they were recorded by botanists as species of Rhytisma occasionally or frequently infested by insects. The fungouslike galls of certain species of Asteromyia Felt have been mentioned in botanical literature and distributed in collections of fungi under the names of Rhytisma asteris and R. solidaginis. The fact that these were really insect galls was brought out by both Peck and Girard in 1876,[1] though Cooke [2] lists them in 1877 as fungi and William Trelease in 1884 presents a somewhat [3] extended discussion of these deformations and concludes that the fungus is able to invade the plant tissues only after injury by the gall midges. In discussing these galls with Professor C. H. Peck, State Botanist, during the latter part of his life, he stated that while they were apparently inhabited by fungus, repeated efforts on his part had failed to demonstrate the existence of any such growth. He was inclined to believe that the thickening or carbonaceous matter was due solely to the irritation produced by the larvae and subsequent pathological conditions, in spite of the fact that fungi belonging to the genus Rhytisma produce apparently identical galls on the leaves of other plants. In this connection, it is noted that Trelease (*Sup. cit*) calls attention to the occurrence of similar tissues in a gall on Impatiens, the producer of which has been described subsequently as Lasioptera impatientifolia Felt, and similar, apparent carbonizing of tissues has also been observed in the gall produced by Lasioptera inustorum Felt. The author's studies of these peculiar fungouslike galls on Solidago and aster have shown them to be inhabited by a considerable series of midges belonging to the genus Asteromyia. In a number of accounts by later botanical writers these peculiar deformities continue to be listed as fungi.[4]

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[1] N. Y. State Museum, 29th Rep't., p. 81, Torr Bot. Club. 6·114.
[2] Buf. Soc. Nat. Sci. Bul. 3:31
[3] Psyche 4:196–200.

The flowerlike gall on cypress, Taxodium distichum, produced by the midge described as Itonida anthici Felt simulates a fungus so closely that this deformation was first described as a fungus under the name of Merulius cupressi (Schrift. d. Naturforsch. Gesell., Leipzig, 1:92, 1822) and subsequently referred to the botanical genus Cyphella (Fries, Epicr. 567, 1836–1838). Dr E. A. Burt of the Missouri Botanical Garden, who called our attention to the situation, states that this insect gall has been distributed in collections of fungi under one or the other of the above mentioned names.

Galls and insect species. Many of the earlier records relating to American species are based upon identifications of the galls or galls and larvae. Are such determinations reliable? A survey o the known food habits of our American species leads us to believe that it is extremely hazardous to identify by gall characters alone an insect inhabiting the simpler flower and leaf bud malformations, especially in the larger botanical families, such as the Compositae and Labiatae. There appear to be a number of midges capable of living in flower or bud galls occurring upon several plants. It is well known, for example, that Asphondylia monacha O. S. may be reared from the flower heads of both solidago and aster. The more highly developed flower bud galls of Rhopalomyia racemicola O. S. and R. anthophila O. S. are, we believe, produced only by the above-named species, although they may be inhabited occasionally by inquilines or zoophagous forms. The same is true to an even more marked degree in the highly specialized, polythalamous bud gall of Schizomyia pomum Walsh and Riley. The more complex leaf bud galls, such as the apical rosettes on Salix, produced by various species of Rhabdophaga, and the compound heads on Solidago, inhabited by several species of Rhopalomyia, are probably the work, in the majority of cases, of certain species, although it should be remembered that these compound galls usually sustain one to several species of inquilines and it is perfectly possible that two apparently very similar galls may in reality be produced by different midges. Great care is necessary in such instances to distinguish between the gall makers, inquilines and zoophagous forms.

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[4] 1899, Jones L. R., and Orton, W. A., Vt. Agr. Expt. Sta., 12th Rpt. p. 171, (Rhytisma solidaginis, listed as fungus).
1910, Wilson, G. W., Iowa Acad. Sci. Proc. 17:57 (Rhytisma solidaginis always contains insects and fungus hyphae, though no spores).
1914, Davis J. J., Wisc. Acad. Sci., Arts & Letters, Trans. 17·864 (Rhytisma solidaginis and R. asteris listed as fungi).

The same is probably true, although to a less extent, of such relatively simple galls as leaf rolls, folded leaf margins and some of the simpler forms of vein or leaf folds. There are certain other somewhat more specialized leaf galls, such as the tumid midrib leaf fold of Contarinia canadensis Felt on ash, and the irregular enlargement of leaf vein or petiole of grape, produced by Lasioptera vitis O. S., which are usually caused by certain species, although in the last named instance it appears probable that the deformity may result from the operations of more than one species, since we have obtained five species representing as many genera from this gall. As in bud galls, so in leaf galls we find certain highly developed malformations which are probably caused by only one species of midge; for example, the characteristic tubular galls on hickory leaves, made by Caryomyia tubicola O. S. There are so many types of galls on hickory foliage and they are known to such a slight degree that we are unable to define with accuracy the galls produced by different species, especially as in a few instances very dissimilar midges appear to have come from identical galls.

The same general considerations apply to stem galls. The simpler and apparently identical enlargements of the stems or subcortical tissues may afford sustenance to very different midges. This is particularly marked in slender twigs of Salix, which latter produce a number of species belonging to varied genera. This is not true of such a specialized gall as that of Phytophaga rigidae O. S. The subcortical and stem galls on plants not having many nearly allied species botanically, are moderately constant in the species they produce.

The location of the gall is more or less variable. Asphondylia monacha O. S. may produce galls in flower heads, in leaf buds and between apposed leaves. The latter, however, is an apparent rather than a real exception, since the deposition of the egg appears to occur while the leaves are still within the bud, and the ultimate location an accident of growth rather than due to variations in habit. Rhopalomyia fusiformis Felt and R. pedicellata Felt produce characteristic galls which may arise from among the flower heads, from the leaves and from the stems in much the same way. Rhopalomyia hirtipes O. S. produces a peculiar apical gall with a spongy cortex on stunted solidago shoots. Recently it has been found that this insect inhabits a dissimilar, though practically identical, subterranean gall developed from the buds on the rootstocks.

It may be inferred from the above that while the identification of midges from gall characters in those producing the more specialized deformities is moderately accurate, such is by no means likely to be the case with the forms inhabiting the simpler types of galls. The most that can be said of the various plant deformities produced is that they are of great service in furnishing a probable clue as to the identity of the insect in the large majority of cases, while in a number they permit of almost positive determination.

Development of the gall. A comparison of the galls produced by midges shows a gradation from a comparatively simple type to the more complex forms. The larvae living exposed upon the leaves in shallow, more or less discolored depressions between folds of a leaf or among the tissues of blossom or leaf buds, represent primitive conditions as far as the development of the phytophagous habit is concerned. It is a comparatively easy step from these conditions to the production of simple leaf or vein folds accompanied usually by some discoloration and, in the more specialized types by much hypertrophy, for example, in the greatly swollen tissues along the midrib of ash produced by Contarinia canadensis Felt. The excessive enlargement in this case can not be attributed to mechanical irritation, since the interior of the gall is smooth and the abnormal growth is in all probability due to the interchange by osmosis of fluid between the apposed animal and vegetable tissues. The tumid enlargements on grape leaves produced by Lasioptera vitis O. S. and its allies appear to vary simply in their mode of formation rather than as to the cause of the swelling, since the larvae in this latter instance occur within the tissues rather than lying upon the surface.

There is abundant evidence to show that Itonid larvae may inhabit vegetable tissues without producing marked abnormalities. This is well illustrated in the case of Cincticornia simpla Felt with its inconspicuous blister enlargement in the leaf of Quercus, the occurrence of Asteromyia vesiculosa Felt in oval, hardly modified swellings upon the leaves of aster and the work of a number of other species. Compare the last named, for instance, with the more common type of Asteromyia galls occurring upon aster and solidago leaves and almost invariably accompanied by a marked carbonaceouslike tissue in the moderate swellings produced by the larvae. It will be observed that cells containing this abnormal product are found beyond the immediate area inhabited by the larvae, indicating a strong probability that there is an interchange by osmosis, of an excretion from the larva which results in this peculiar condition.

The same phenomenon, though perhaps not to so marked an extent, is seen in certain bud galls on willow, especially those produced by Rhabdophaga triticoides Walsh. An examination of the developing galls in June, easily detected by the closely grouped mass of abnormal leaves, shows that the larvae occur near the center of incipient buds and are each surrounded by a shell of brownish, hardened tissue apparently arrested in its development by excretions from the larva, since this central, shell-like cell is inclosed by a softer, apparently normal growth.

The arrest of development at a growing point, such as a bud, explains the peculiar, simple or compound, rosette galls so frequently observed upon willow and solidago, respectively.

Evidence that the growth of the gall is contingent in large measure upon the activity of the larva and presumably its continued production of a more or less irritant fluid, may be found in the development of the peculiar apical gall of Phytophaga rigidae O. S. Our attention was attracted several years ago to one or two clumps of willows apparently affected by this insect, yet presenting a peculiar appearance in that the galls were markedly smaller, slender and somewhat different in shape from the typical podlike enlargement produced by this species. Rearing from these abnormal galls resulted in obtaining nothing but parasites, showing that in all probability the early destruction of the larvae had removed the source of irritation and arrested the normal enlargement of the gall.

The development of the more complex leaf gall is probably contingent in large measure at least, upon the continued activity of the larva and presumably has its inception in most cases as an inconspicuous yellowish discoloration upon the surface of the leaf. This is evidenced by the development of the gall in Caryomyia tubicola O. S. which, according to the late Dr M. T. Thompson appears in late June or early July as a nearly circular, yellowish or yellowish green blister on the upper surface of the leaf. Its position is marked on the underside by a pale yellowish color surrounded by a reddish, spongy growth adorned with numerous rather long plant hairs. Early in August this deformity may be observed as a minute, yellowish green or black nipple protruding from the developing socket. The galls continue to increase in length and become full grown the latter part of August or early in September. Small, partly grown galls occasionally seen the latter part of August or early September are usually empty, indicating a probable arrest in the development of the growth following the destruction of its maker by parasites.

It is probable that the tubular leaf galls, such as those produced by Hormomyia verruca Walsh on willow, the similar one caused by Hormomyia canadensis Felt on Amelanchier, or the much more produced tubular, curved, green gall occasionally found on Cornus amomum, all originate as inconspicuous blisters. The peculiar hypertrophy in each of these and similar cases is probably brought about by the action of an irritant fluid from the larva upon definite leaf areas. There appears to be no reason in any of the above mentioned instances to assume that mechanical irritation is a necessary corollary to the production of these plant deformities. In not a few instances, the gall results from a chemical stimulus.

Similar conditions appear to hold in the production of stem galls, since it is comparatively easy to find species producing very little or no enlargement, such for example, as Sackenomyia packardi Felt and several other species attacking the slender twigs of willow. Here we have mechanical irritation, due to the boring of the larvae, with very little or no enlargement, although the insect must derive its nournishment from adjacent tissues. On the other hand, Rhabdophaga podagrae Felt produces a uniform enlargement in willow twigs and the same is true of Lasioptera humulicaulis Felt in the swollen stems of the wild hop, Humulus. The interior of the stems inhabited by these latter species is distinctly blackened, apparently due to the work of the larva. A somewhat similar condition is produced in Hibiscus stems by Neolasioptera hibisci Felt, except that this species works here and there in the stems and produces an enlargement approximately correlated to the degree of infestation. Similar conditions prevail in the case of many other of our American species.

It is worthy of note that the majority of the Itonididae affecting living plants restrict their attack to a season when growth is rapid and the tissues succulent and therefore tender, or confine themselves in large measure to portions of the plant where such conditions obtain. The first is strikingly illustrated in the production of a number of generations annually by Phytophaga destructor Say, provided its food plant is in a condition favorable to the propagation of the species. The second is shown by the obvious preference exhibited by midges for fruit, bud and leaf galls, over 70 per cent of the species affecting these tissues as compared with 30 per cent occurring in the relatively harder stem galls. These figures hardly exhibit the true condition of affairs, since a number of the stem galls at least, have their inception at a time when the tissues are relatively soft, while many of the leaf deformities (for example, the long series of hickory galls produced by Caryomyia) commence their development while the foliage is young and tender. Incidentally it may be noted that the larger and more complex deformities are found in association with fruit and bud galls, places where the tissues are very tender and the vital forces of the plant most active.

FOOD HABITS

The following list of hosts, host plants and galls should prove of much service in identifying the species of Itonididae, and also, the food plants, it will be observed, have been grouped according to their botanical affinities, the arrangement and nomenclature of Gray's New Manual of Botany, seventh edition, being the one adopted. This table lists 202 plant genera belonging to sixty-nine families known to support some 698 species of gall midges representing 69 genera. In addition to the above there are some five species reared from unknown plants and eleven species belonging to three genera known to be zoophagous, making a total of 709 species representing sixty-nine insect genera.

A study of this record, summarized in the following table of host plants, reveals some exceedingly interesting conditions. The highly specialized, widely distributed and frequently abundant Compositae support a very large fauna. Some thirty-seven plant genera belonging to this family afford sustenance to 151 species of gall midges representing some fifteen genera. The majority of these midges, eighty-two species, occur in bud galls, thirty-nine in leaf galls, forty-one in stem galls, while four inhabit fruit galls, using this term in a general sense. The Salicaceae, represented only by Salix and Populus, support some sixty-one species of gall midges belonging to sixteen genera, by far the greater majority occurring upon the numerous species of Salix. It will be seen that in this plant family, as in the Compositae, a large proportion, namely twenty-one species, occur in bud galls, sixteen in leaf galls, twenty-one in stem galls and one living at the expense of the fruit. The Rosaceae appears to be the next plant family favored by gall midges, eleven genera being subject to attack by fifty-five species of midges assignable to nineteen genera. It will be seen that a relatively larger number of species than in the preceding plant families, namely twenty-nine, occur in leaf galls, while but seven produce bud galls. The Gramineae or grasses with their numerous genera and species occurring under varied conditions, have but twenty-one genera at present known to support some thirty-three species of midges representing seventeen genera. It is probable that this relatively small number of midges attacking grasses is due to the difficulty of detecting their work in the Gramineae. There is a striking parallelism between the Juglandaceae and the Fagaceae, two plant genera in each being affected by gall midges. Juglans and Castanea are each known to be infested by one and four species, respectively, while Carya and Quercus are subject to attack by twenty-five and twenty-six species, the former affording support to representatives of six, and the latter to species referable to eleven genera. Carya and Quercus are likewise comparable in that each supports but one species living upon the fruit, while by far the great majority of the species, namely twenty-three and nineteen, respectively, produce leaf galls. It will be seen by reference to the summary that some fifty-two species live in the fruit, 198 in bud galls, 255 in leaf galls, 173 in stem galls, while only six are known to occur in root galls. It is more than probable that the last named figure is relatively much lower than the others owing to practical difficulties in finding root galls.

It is evident that the family is an exceedingly plastic one as a whole and that certain genera have adapted themselves in a marvelous degree to various food plants. This is strikingly illustrated in the genus Rhabdophaga and its occurrence in a large number of species upon Salix, and the genera Lasioptera, Neolasioptera and Asteromyia, all closely related, and their almost exclusive restriction to Solidago and Aster in the Compositae. Carya has its special type in the numerous species of Caryomyia occurring upon the leaf, while Quercus presents an analogous condition in the restriction of Cincticornia to the foliage of this tree.

It is interesting to compare the above with the recently summarized records[1] for European Itonididae. It will be noted first of all that the food habits of some 420 European species representing forty-three genera are known. The Pinaceae affords sustenance to eleven species belonging to four genera, a condition closely paralleled in America. The European Gramineae are infested by some twenty species representing seven genera, the number of genera and species falling somewhat below what we find in this country. On the other hand, the European records for the Cyperaceae include four genera and nine species, while in this country but one genus has been reared from Scirpus, although it is probable that subsequent work will result in our obtaining a number of species of Hormomyia from plants belonging in this family. The European Salicaceae support some thirty species belonging to six genera, five of these occurring on Populus. It will be noted that we have obtained a considerably larger number of both genera and species from Salix in this country. There appear to be no midges affecting Juglandaceae in Europe, though we have some twenty-one species representing six genera. There are nearly as many species and genera, twenty and seven respectively, affecting the Fagaceae in Europe as in America, although they are differently distributed, since Fagus supports five species referable to three genera and Quercus has only fourteen species representing four genera, a marked contrast to the twenty-one species and seven genera attacking the oaks in this country. There are markedly fewer midges living upon the Rosaceae in Europe than in America. This is especially marked in Spiraea with its two genera and five species compared with our eight genera and ten species. A still more striking contrast is found in the Vitaceae, the European Vitis supporting but two genera and two species, while our American grapes afford sustenance to some fifteen species belonging to twelve genera. The number of species living upon the Compositae is also much less, namely, some sixty-seven species representing ten genera. This is accounted for in part by our very large fauna of the Solidago and the somewhat numerous species living upon aster, plant genera which in Europe support only one genus and one species each.

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[1] 1908, Houard, C. Les Zoocecidies des Plantes d'Europe et du Bassin de la Mediterranee, v. 1 and 2.

Miscellaneous food habits. The above discussion has been limited to the phytophagous species. There are in addition, as listed elsewhere, certain other species which belong in a different category. One of the more specialized of these is the European Endaphis perfidus Kieff., an endoparasite on aphids. Two American species apparently prey upon leaf mites, Eriophyidae. There are a number of American ectoparasites in this group referable to the genus Aphidoletes, while species of Lestodiplosis similarly live at the expense of certain gall-making Itonididae and upon colonies of Miastor larvae. The European Lestodiplosis liviae Rübs. preys upon a Psyllid, Livia juncorum, while the American Dentifibula cocci Felt, Coccidomyia pennsylvanica Felt and Cecidomyia coccidarum Ckll. have been reared from species of Coccidae, namely, Aspidiotus uvae Comst., a Lecanium on beech leaves and from Orthezia and Dactylopius on Coleus, respectively. The American Mycodiplosis acarivora Felt preys upon red spider, Tetranychus, on lemon. Several species are known to live upon fungi, namely, Mycophila fungicola Felt, on young mushrooms and two species of Mycodiplosis among oecidial growths on different plants. Arthrocnodax macrofila Felt has been reared from an unknown fungus, while A. apiphila was obtained from bee hives under conditions which lead us to suspect that it may play the role of scavenger. A Cecidomyid larva, adult unknown, has been recorded by Marlatt[1] as an egg parasite of Tibicen septendecim. It is probably a predaceous species taking advantage of this exceptional food supply whenever conditions permit. Pergande, in an unpublished record of the United States Bureau of Entomology, states that he found Diplosid larvae in a breeding jar containing twigs infested with eggs of the periodical Cicada. The very interesting Cordylomyia coprophila Felt was reared from manure.

Table of host plants

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Polypodiaceae	.....	.....	.....	.....	.....	.....	......
Cystopteris	1	1	.....	.....	.....	.....	1
Orchidaceae	.....	.....	.....	.....	.....	.....	......
Cattleya	1	1	.....	.....	.....	.....	1
Salicaceae	*16*	*61*	*1*	*21*	*16*	*21*	......
Salix	12	47	1	21	5	20	......
Populus	7	14	.....	.....	11	1	......
Myricaceae	.....	.....	.....	.....	.....	.....	......
Myrica	2	2	.....	1	1	.....	......
Juglandaceae	*6*	*26*	*1*	.....	*24*	.....	......
Juglans	1	1	.....	.....	1	.....	......
Carya (Hicoria)	6	25	1	.....	23	.....	......
Betulaceae	*8*	*11*	*2*	*1*	*4*	.....	......
Corylus	3	3	1	.....	2	.....	......
Ostrya	1	1	.....	.....	1	.....	......
Carpinus	1	1	.....	.....	1	.....	......
Betula	5	5	1	.....	.....	.....	......
Alnus	1	1	.....	1	.....	.....	......
Fagaceae	*14*	*34*	*1*	*3*	*21*	*1*	......
Castanea	6	7	1	1	2	.....	......
Castanopsis	1	1	.....	1	.....	.....	......
Quercus	11	26	1	1	19	1	......

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[1] 1907, U. S. Dep't Agr. Bur. Ent. Bul. 71, p. 129.

Table of host plants (*continued*)

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Urticaceae	*5*	*18*	.....	*2*	*9*	*7*	......
Ulmus	3	3	.....	1	1	1	......
Celtis	2	9	.....	.....	6	3	......
Humulus	1	1	.....	.....	.....	1	......
Urtica	1	2	.....	.....	2	.....	......
Laportea	1	2	.....	1	.....	1	......
Boehmeria	1	1	.....	.....	.....	1	......
Ficus	1	1	1	.....	.....	.....	......
Aristolochiaceae	.....	.....	.....	.....	.....	.....	......
Aristolochia	1	1	.....	.....	1	.....	......
Polygonaceae	*3*	*4*	*1*	*1*	*5*	.....	......
Eriogonum	1	1	.....	1	.....	.....	......
Rumex	1	2	1	.....	.....	.....	......
Coccolobis	1	1	.....	.....	5	.....	......
Chenopodiaceae	*6*	*11*	*1*	*2*	*4*	.....	......
Eurotia	1	1	.....	1	.....	.....	......
Sarcobatus	3	3	.....	1	2	.....	......
Atriplex	3	6	1	.....	1	4	......
Suaeda	1	1	.....	.....	1	.....	......
Phytolaccaceae	.....	.....	.....	.....	.....	.....	......
Rivina	1	1	.....	1	.....	.....	......
Nyctaginaceae	*2*	*4*	.....	.....	*1*	*3*	......
Oxybaphus	1	1	.....	.....	.....	1	......
Pisonia	1	3	.....	.....	1	2	......
Gnetaeceae	.....	.....	.....	.....	.....	.....	......
Ephedra	1	2	.....	.....	.....	2	......
Pinaceae	*19*	*33*	*3*	*15*	*10*	*9*	......
Pinus	9	19	.....	2	6	7	......
Picea	1	1	.....	.....	1	.....	......
Tsuga	1	1	.....	.....	.....	1	......
Abies	4	4	1	1	2	.....	......
Taxodium	3	4	1	1	1	1	......
Chamaecyparis	2	2	1	1	.....	.....	......
Sabina	2	2	.....	2	.....	.....	......
Thuja	1	1	.....	1	.....	.....	......
Juniperus	6	8	.....	7	.....	.....	......
Gramineae	*17*	*33*	*9*	*2*	.....	*22*	......
Grass	1	1	.....	.....	.....	1	......
Secale	2	2	1	.....	.....	1	......
Triticum	3	5	3	.....	.....	2	......
Tripsacum	1	1	.....	.....	.....	1	......
Sorghum	1	1	1	.....	.....	.....	......
Panicum	1	2	.....	.....	.....	2	......
Echinochloa	1	1	.....	1	.....	.....	......
Setaria	1	1	1	.....	.....	.....	......
Muhlenbergia	2	2	.....	.....	.....	2	......
Phleum	1	1	.....	.....	.....	1	......
Alopecurus	1	1	1	.....	.....	.....	......
Agrostis	2	2	1	.....	.....	1	......
Avena	3	3	.....	.....	.....	3	......
Danthonia	1	1	.....	.....	.....	?1	......
Tridens	1	1	1	.....	.....	.....	......
Eragrostis	1	1	.....	.....	.....	?1	......
Distichlis	1	1	.....	1	.....	.....	......
Poa	1	2	.....	.....	.....	?2	......
Agropyron	1	1	.....	.....	.....	1	......

Table of host plants (*continued*)

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Hordeum	1	1	.....	.....	.....	1	......
Elymus	2	2	.....	.....	.....	2	......
Cyperaceae	*3*	*3*	*1*	*1*	.....	.....	......
Cyperus	1	1	.....	1	.....	.....	......
Dulichium	1	1	1	.....	.....	.....	......
Scirpus	1	1	.....	.....	.....	?1	......
Juncaceae	.....	.....	.....	.....	.....	.....	......
? Juncus	1	1	1	.....	.....	.....	......
Liliaceae	*5*	*12*	*2*	*1*	*6*	*1*	*1*
Oakesia	1	1	.....	.....	1	.....	......
Yucca	2	2	1	.....	.....	1	......
Smilacina	2	2	1	.....	.....	.....	......
Maianthemum	2	2	.....	.....	1	.....	1
Polygonatum	1	1	.....	1	.....	.....	......
Smilax	3	4	.....	.....	4	.....	......
Dioscoreaceae	.....	.....	.....	.....	.....	.....	......
Dioscorea	1	1	.....	.....	.....	1	......
Ranunculaceae	*8*	*9*	*1*	*5*	.....	.....	*1*
Thalictrum	2	2	1	.....	.....	.....	......
Anemone	1	1	.....	1	.....	.....	......
Clematis	[illegible]	5	.....	4	.....	.....	......
Paeonia	1	1	.....	.....	.....	.....	1
Magnoliaceae	.....	.....	.....	.....	.....	.....	......
Liriodendron	2	3	.....	.....	3	.....	......
Lauraceae	*3*	*3*	.....	.....	*2*	*1*	......
Sassafras	1	1	.....	.....	1	.....	......
Benzoin	2	2	.....	.....	1	1	......
Papaveraceae	.....	.....	.....	.....	.....	.....	......
Papaver	1	1	.....	.....	.....	1	......
Cruciferae	*1*	*3*	*2*	*1*	.....	.....	......
Lepidium	1	1	1	.....	.....	.....	......
Sisymbrium	1	1	.....	1	.....	.....	......
Stanleya	1	1	1	.....	.....	.....	......
Capparidaceae	.....	.....	.....	.....	.....	.....	......
Cleome	1	1	1	.....	.....	.....	......
Saxifragaceae	*5*	*5*	*1*	*2*	*1*	*1*	......
Hydrangea	1	1	.....	1	.....	.....	......
Ribes	4	4	1	1	1	?1	......
Hamamelidaceae	.....	.....	.....	.....	.....	.....	......
Hamamelis	2	4	.....	.....	4	.....	......
Platanaceae	.....	.....	.....	.....	.....	.....	......
Platanus	1	1	.....	.....	1	.....	......
Rosaceae	*19*	*55*	*3*	*7*	*29*	*7*	......
Spiraea	9	12	.....	.....	7	4	......
Pyrus	1	1	1	.....	.....	.....	......
Cercocarpus	1	1	.....	1	.....	.....	......
Amelanchier	3	5	.....	.....	5	.....	......
Crataegus	7	12	.....	.....	10	.....	......
Fragaria	1	1	.....	.....	1	.....	......
Potentilla	1	1	.....	.....	.....	1	......
Rubus	4	5	.....	1	3	1	......
Agrimonia	1	1	.....	1	.....	.....	......
Rosa	4	4	.....	4	1	.....	......
Prunus	9	12	2	1	2	1	......

Table of host plants (*continued*)

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Leguminosae	*6*	*26*	*4*	*4*	*8*	*9*	......
Prosopis	2	2	1	1	.....	.....	......
Gleditsia	2	2	.....	.....	1	1	......
Cassia	1	1	.....	.....	.....	1	......
Thermopsis	1	1	.....	1	.....	.....	......
Crotalaria	1	1	.....	.....	.....	1	......
Genista	1	1	.....	.....	1	.....	......
Lupinus	4	4	.....	.....	1	2	......
Trifolium	1	2	1	.....	1	.....	......
Medicago	2	2	1	.....	.....	.....	......
Robinia	2	2	.....	.....	2	.....	......
Desmodium	4	4	.....	2	.....	2	......
Lespedeza	2	2	1	.....	1	1	......
Lathyrus	1	1	.....	.....	1	.....	......
Amphicarpa	1	1	.....	.....	.....	1	......
Geraniaceae	.....	.....	.....	.....	.....	.....	......
Geranium	1	1	.....	.....	1	.....	......
Zygophyllaceae	.....	.....	.....	.....	.....	.....	......
Covillea	1	2	.....	?1	.....	.....	......
Euphorbiaceae	*4*	*5*	*2*	*1*	*2*	.....	......
Manihot	2	2	.....	.....	2	.....	......
Acalypha	1	1	.....	1	.....	.....	......
Phyllanthus	1	1	1	.....	.....	.....	......
Euphorbia	1	1	1	.....	.....	.....	......
Buxaceae	.....	.....	.....	.....	.....	.....	......
Buxus	1	1	.....	.....	1	.....	......
Anacardiaceae	*7*	*7*	.....	*1*	*1*	*3*	*1*
Mangifera	2	2	.....	.....	1	1	......
Rhus	5	5	.....	1	.....	2	1
Aquifoliaceae	.....	.....	.....	.....	.....	.....	......
Nemopanthus	1	1	.....	1	.....	.....	......
Celastraceae	*3*	*3*	.....	.....	*1*	*2*	......
Pachistima	1	1	.....	.....	1	.....	......
Celastrus	2	2	.....	.....	.....	2	......
Aceraceae	.....	.....	.....	.....	.....	.....	......
Acer	7	10	.....	2	7	1	......
Balsaminaceae	.....	.....	.....	.....	.....	.....	......
Impatiens	3	4	1	.....	1	2	......
Rhamnaceae	.....	.....	.....	.....	.....	.....	......
Ceanothus	1	1	.....	1	.....	.....	......
Vitaceae	*15*	*22*	.....	*4*	*14*	*2*	......
Psedera	1	2	.....	.....	1	1	......
Vitis	13	19	.....	4	13	.....	......
Cissus	1	1	.....	.....	.....	1	......
Tiliaceae	.....	.....	.....	.....	.....	.....	......
Tilia	4	4	.....	.....	3	1	......
Malvaceae	*6*	*6*	.....	*2*	*1*	*2*	......
Kosteletzkya	1	1	.....	1	.....	.....	......
Gossypium	4	4	.....	1	1	1	......
Hibiscus	1	1	.....	.....	.....	1	......
Hypericaceae	.....	.....	.....	.....	.....	.....	......
Hypericum	3	3	.....	1	.....	2	......
Violaceae	.....	.....	.....	.....	.....	.....	......
Viola	3	3	1	.....	1	.....	......
Loasaceae	.....	.....	.....	.....	.....	.....	......
Mentzelia	1	1	.....	1	.....	.....	......

Table of host plants (*continued*)

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Cactaceae	.....	.....	.....	.....	.....	.....	.....
Opuntia	2	4	2	.....	?2	.....	.....
Elaeagnaceae	.....	.....	.....	.....	.....	.....	.....
Shepherdia	1	1	.....	1	.....	.....	.....
Myrtaceae	.....	.....	.....	.....	.....	.....	.....
Eugenia	2	2	1	.....	1	.....	.....
Lythraceae	.....	.....	.....	.....	.....	.....	.....
Decodon	1	1	.....	1	.....	.....	.....
Onagraceae	.....	.....	.....	.....	.....	.....	.....
Zauschneria	1	1	.....	1	.....	.....	.....
Umbelliferae	*3*	*4*	.....	.....	*2*	*3*	.....
Sanicula	1	1	.....	.....	1	1	.....
Cicuta	1	1	.....	.....	1	.....	.....
Zizia	1	1	.....	.....	.....	1	.....
Angelica	1	1	.....	.....	.....	1	.....
Cornaceae	*4*	*7*	.....	*1*	*3*	*3*	.....
Garrya	1	1	.....	1	.....	.....	.....
Cornus	3	4	.....	.....	2	2	.....
Nyssa	1	2	.....	.....	1	1	.....
Ericaceae	*4*	*5*	*1*	*2*	*2*	.....	.....
Rhododendron	1	1	.....	1	.....	.....	.....
Gaylussacia	1	1	.....	.....	1	.....	.....
Vaccinium	3	3	1	1	1	.....	.....
Primulaceae	.....	.....	.....	.....	.....	.....	.....
Lysimachia	1	1	.....	1	.....	.....	.....
Sopotaceae	.....	.....	.....	.....	.....	.....	.....
Bumelia	1	1	.....	?1	.....	.....	.....
Oleaceae	.....	.....	.....	.....	.....	.....	.....
Fraxinus	8	10	.....	1	8	.....	.....
Apocynaceae	.....	.....	.....	.....	.....	.....	.....
Apocynum	2	2	.....	1	.....	.....	.....
Asclepiadaceae	.....	.....	.....	.....	.....	.....	.....
Asclepias	3	4	.....	.....	2	1	.....
Convolvulaceae	*3*	*3*	.....	*2*	.....	*1*	.....
Ipomoea	2	2	.....	2	.....	.....	.....
Convolvulus	1	1	.....	.....	.....	1	.....
Boraginaceae	.....	.....	.....	.....	.....	.....	.....
Amsinckia	1	1	.....	1	.....	.....	.....
Verbenaceae	*5*	*6*	.....	*2*	*1*	*2*	.....
Verbena	4	4	.....	.....	1	2	.....
Stachytarpha	1	1	.....	1	.....	.....	.....
Clerodendron	1	1	.....	1	.....	.....	.....
Labiatae	*6*	*15*	.....	*4*	*3*	*7*	*1*
Audibertia	1	1	.....	.....	.....	1	.....
Scutellaria	1	1	.....	.....	.....	1	.....
Galeopsis	1	1	.....	.....	.....	1	.....
Salvia	1	1	.....	.....	1	.....	.....
Monarda	1	2	.....	.....	.....	1	1
Lycopus	1	2	.....	.....	.....	2	.....
Mentha	4	5	.....	4	.....	1	.....
Collinsonia	1	2	.....	.....	2	.....	.....
Solanaceae	*2*	*2*	*1*	.....	.....	*1*	.....
Lycopersicum	1	1	1	.....	.....	.....	.....
Solanum	1	1	.....	.....	.....	1	.....
Scrophulariaceae	*5*	*6*	*1*	*2*	.....	*3*	.....
Scrophularia	1	1	.....	1	.....	.....	.....

Table of host plants (*concluded*)

BOTANICAL FAMILY: GENERA	INSECT GENERA	INSECT SPECIES	FRUIT GALLS	BUD GALLS	LEAF GALLS	STEM GALLS	ROOT GALLS
Pentstemon	1	1	.....	.....	.....	1	.....
Mimulus	1	1	.....	.....	.....	1	.....
Diplacus	2	2	.....	1	.....	1	.....
Gerardia	1	1	1	.....	.....	.....	.....
Bignoniaceae	*1*	*2*	*1*	*1*	*1*	.....	.....
Tecoma	1	1	.....	.....	1	.....	.....
Catalpa	1	1	1	1	.....	.....	.....
Plantaginaceae	.....	.....	.....	.....	.....	.....	.....
Plantago	1	1	.....	.....	.....	.....	.....
Rubiaceae	.....	.....	.....	.....	.....	.....	.....
Galium	1	1	.....	1	.....	.....	.....
Cephalanthus	1	1	.....	.....	.....	1	.....
Caprifoliaceae	*10*	*17*	.....	*5*	*8*	*4*	.....
Diervilla	2	2	.....	1	.....	1	.....
Lonicera	1	1	.....	1	.....	.....	.....
Symphoricarpus	2	2	.....	.....	1	1	.....
Viburnum	5	8	.....	1	6	1	.....
Sambucus	4	4	.....	2	1	1	.....
Cucurbitaceae	.....	.....	.....	.....	.....	.....	.....
Cucumeris	2	2	.....	1	.....	.....	.....
Compositae	*20*	*143*	*4*	*82*	*39*	*41*	.....
Vernonia	3	3	.....	2	.....	.....	.....
Eupatorium	7	8	.....	5	.....	3	.....
Grindelia	2	2	.....	2	.....	.....	.....
Gutierrezia	2	2	.....	1	.....	1	.....
Chrysopsis	1	1	.....	1	.....	.....	.....
Solidago	9	46	.....	26	19	7	.....
Bigelovia	5	11	.....	6	1	5	.....
Aster	5	21	.....	4	12	5	.....
Erigeron	3	3	.....	1	1	1	.....
Sericocarpus	1	1	.....	1	.....	.....	.....
Baccharis	3	5	.....	2	.....	4	.....
Ericameria	1	1	.....	1	.....	.....	.....
Antennaria	2	3	.....	3	.....	.....	.....
Gnaphalium	1	1	.....	1	.....	.....	.....
Parthenium	1	1	.....	1	.....	.....	.....
Ambrosia	1	1	.....	.....	.....	1	.....
Rudbeckia	3	4	.....	2	.....	2	.....
Lepachys	1	1	.....	1	.....	.....	.....
Helianthus	5	10	1	2	1	6	.....
Actinomeris	1	1	.....	1	.....	.....	.....
Bidens	1	1	.....	.....	.....	1	.....
Helenium	2	2	.....	1	.....	1	.....
Achillea	2	2	2	.....	.....	.....	.....
Anthemis	1	1	1	.....	.....	.....	.....
Chrysanthemum	1	1	.....	1	1	1	.....
Artemisia	4	13	.....	12	3	.....	.....
Erechtites	1	1	.....	.....	.....	1	.....
Senecio	2	2	.....	1	.....	1	.....
Arctium	1	1	.....	?1	.....	.....	.....
Cirsium	1	1	.....	1	.....	.....	.....
Lactuca	1	1	.....	.....	.....	1	.....
Encelia	1	2	.....	2	.....	.....	.....
Prenanthes	1	1	.....	.....	1	.....	.....
Totals	69	698	52	198	255	173	6

Food habits of Itonid genera

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Lestremiinariae[1]	....	....	....	....	....	....	*39*	......
Catocha[2]	....	....	....	....	....	....	*3*	......
Lestremia	....	....	....	....	....	....	*16*	......
Microcerata	....	....	....	....	....	....	*10*	......
Konisomyia	....	....	....	....	....	....	*2*	......
Tritozyga	....	....	....	....	....	....	*3*	......
Neptunimyia	....	....	....	....	....	....	*2*	......
Neocatocha	....	....	....	....	....	....	*3*	......
Campylomyzariae	....	....	....	....	....	*1*	*68*	......
Joannisia	....	....	....	....	....	....	*8*	......
Paeonia	....	....	....	....	?1	....	.....	......
Mycophila	....	....	....	....	....	1	.....	......
Ceratomyia	....	....	....	....	....	....	*1*	......
Campylomyza	....	....	....	....	....	....	*12*	......
Prionelius	....	....	....	....	....	....	*15*	......
Monardia	....	....	....	....	....	....	*16*	......
Pinus	....	....	....	....	....	....	2	......
Cordylomyia	....	....	....	....	....	....	*10*	......
Corinthomyia	....	....	....	....	....	....	*4*	......
Heteropezinae	....	....	*2*	*1*	....	....	*22*	......
Miastor	....	....	....	....	....	....	*1*	......
Acer	....	....	....	....	....	....	1	......
Betula	....	....	....	....	....	....	1	......
Carya	....	....	....	....	....	....	1	......
Castanea	....	....	....	....	....	....	1	......
Fagus	....	....	....	....	....	....	1	......
Quercus	....	....	....	....	....	....	1	......
Ulmus	....	....	....	....	....	....	1	......
Johnsonomyia	....	....	....	....	....	....	*3*	......
Leptosyna	....	....	....	....	....	....	*1*	......
Quercus	....	....	....	....	....	....	1	......
Epimyia	....	....	....	....	....	....	*1*	......
Kronomyia	....	....	....	....	....	....	*1*	......
Populus	....	....	....	....	....	....	1	......
Brachyneura	....	....	....	....	....	....	*3*	......
Eupatorium	....	....	....	1	....	....	.....	......
Vitis	....	....	1	....	....	....	.....	......
Unknown	....	....	?1	....	....	....	.....	......
Oligarces	....	....	....	....	....	....	*2*	......
Ulmus	....	....	....	....	....	....	1	......
Porricondylariae	....	....	*3*	*5*	....	*1*	*7*	......
Winnertzia	....	....	....	....	....	....	*13*	......
Acer	....	....	....	....	....	....	1	......
Castanea	....	....	....	....	....	....	1	......
Crataegus	....	....	....	....	....	....	1	......
Lenzites	....	....	....	....	....	1	.....	......
Pinus	....	....	....	....	....	....	1	......
Parwinnertzia	....	....	....	....	....	....	*1*	......
Didactylomyia	....	....	....	....	....	....	*5*	......
Colpodia	....	....	....	....	....	....	*19*	......
Fraxinus	....	....	?1	....	....	....	.....	......
Poa	....	....	....	?1	....	....	.....	......
Tilia	....	....	?1	....	....	....	.....	......

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[1] Numerals in italics opposite family names indicate the number of species reared.

[2] Numerals in italics opposite genera and families indicate the total number of American species known, the location in columns, the presumable habit.

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	leaf galls	Stem gall	Root galls	Fungivorous	Phytophagous	Zoophagous
Asynapta	....	....	....	....	....	....	16	......
Mangifera	....	....	....	1	....	....	.....	......
Rhus	....	....	....	1	....	....	.....	......
Salix	....	....	....	1	....	....	.....	......
Porricondyla	....	....	....	....	....	....	28	......
Gossypium	....	....	....	1	....	....	.....	......
Tilia	....	....	?1	....	....	....	.....	......
Camptomyia	....	....	....	....	....	....	7	......
Tsuga	....	....	....	....	....	....	1	......
Dirhiza	....	....	....	....	....	....	6	......
Holoneurus	....	....	....	....	....	....	8	......
Ficus	....	....	....	....	....	....	1	......
Hormosomyia	....	....	....	....	....	....	1	......
Dasyneuriariae	12	44	46	17	3	1	1	......
Rhabdophaga	....	13	5	12	....	....	36	......
Acer	....	....	2	....	....	....	.....	......
Carya	....	....	?1	....	....	....	.....	......
Cephalanthus	....	....	....	1	....	....	.....	......
Elymus	....	....	....	1	....	....	.....	......
Picea	....	1	....	....	....	....	.....	......
Populus	....	?1	....	....	....	....	.....	......
Rosa	....	1	....	....	....	....	.....	......
Salix	....	9	1	10	....	....	.....	......
Spiraea	....	....	1	....	....	....	.....	......
Vitis	....	?1	....	....	....	....	.....	......
Dasyneura	11	27	26	2	3	1	88	......
Abies	1	....	....	....	....	....	.....	......
Acer	....	....	3	....	....	....	.....	......
Agrostis	1	....	....	....	....	....	.....	......
Alnus	....	1	....	....	....	....	.....	......
Anemone	....	1	....	....	....	....	.....	......
Bigelovia	....	1	....	....	....	....	.....	......
Cercocarpus	....	1	....	....	....	....	.....	......
Cirsium	....	1	....	....	....	....	.....	......
Cissus	....	....	1	....	....	....	.....	......
Clematis	....	1	....	....	....	....	.....	......
Eugenia	1	....	....	....	....	....	.....	......
Eupatorium	....	1	....	....	....	....	.....	......
Fraxinus	....	....	3	....	....	....	.....	......
Fungus	....	....	....	....	....	1	.....	......
Galium	....	1	....	....	....	....	.....	......
Genista	....	....	1	....	....	....	.....	......
Gleditsia	....	....	1	....	....	....	.....	......
Hypericum	....	1	....	....	....	....	.....	......
Lathyrus	....	....	1	....	....	....	.....	......
Lepidium	1	....	....	....	....	....	.....	......
Lupinus	....	....	2	1	....	....	.....	......
Lysimachia	....	1	....	....	....	....	.....	......
Maianthemum	....	....	....	....	1	....	.....	......
Mentha	....	2	....	....	....	....	.....	......
Picea	1	....	....	....	....	....	.....	......
Prunus	1	....	....	....	....	....	.....	......
Psedera	....	....	3	....	....	....	.....	......
Quercus	1	....	1	....	....	....	.....	......
Rhus	....	....	....	....	1	....	.....	......

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Ribes	1	....	....	....	....	....	.....	......
Robinia	....	....	1	....	....	....	.....	......
Rosa	....	1	1	....	....	....	.....	......
Rubus	....	1	....	....	....	....	.....	......
Salix	....	6	1	1	....	....	.....	......
Sassafras	....	....	1	....	....	....	.....	......
Sisymbrium	....	1	....	....	....	....	.....	......
Smilacina	....	....	....	....	1	....	.....	......
Smilax	....	....	1	....	....	....	.....	......
Solidago	....	3	1	....	....	....	.....	......
Stanleya	....	1	....	....	....	....	.....	......
Trifolium	1	....	1	....	....	....	.....	......
Ulmus	....	1	....	....	....	....	.....	......
Vaccinium	....	1	2	....	....	....	.....	......
Vegetable matter	....	....	....	....	....	?	1	......
Viola	1	....	....	....	....	....	.....	......
Vitis	....	....	1	....	....	....	.....	......
Yucca	1	....	....	....	....	....	.....	......
Lasiopteryx	....	....	*3*	*1*	....	*1*	*7*	......
Corylus	....	....	1	....	....	....	.....	......
Ficus	....	....	....	1	....	....	.....	......
Manihot	....	....	?1	....	....	....	.....	......
Quercus	....	....	....	....	....	?1	.....	......
Vitis	....	....	1	....	....	....	.....	......
Neuromyia	....	....	....	....	....	....	*1*	......
Dryomyia	....	....	....	....	....	....	*1*	......
Solidago	....	1	....	....	....	....	.....	......
Cystiphora	....	....	....	....	....	....	*2*	......
Prenanthes	....	....	1	....	....	....	.....	......
Viburnum	....	....	1	....	....	....	.....	......
Procystiphora	....	....	....	....	....	....	*1*	......
? Salix	....	....	....	?1	....	....	.....	......
Rhizomyia	*1*	....	*5*	....	....	....	*8*	......
Crataegus	....	....	2	....	....	....	.....	......
Fraxinus	....	....	1	....	....	....	.....	......
Populus	....	....	1	....	....	....	.....	......
Prunus	1	....	....	....	....	....	.....	......
Vitis	....	....	1	....	....	....	.....	......
Microperrisia	....	....	....	....	....	....	.....	*1*
Pulvinaria	....	....	....	....	....	....	.....	1
Allomyia	....	....	....	....	....	....	*1*	......
Juniperus	....	1	....	....	....	....	.....	......
Ctenodactylomyia	....	....	....	....	....	....	*1*	......
Coccolobis	....	....	1	....	....	....	.....	......
Diarthronomyia	....	....	....	....	....	....	*5*	......
Artemisia	....	2	3	....	....	....	.....	......
Chrysanthemum	....	....	1	1	....	....	.....	......
Coccidomyia	....	....	....	....	....	....	.....	*1*
Lecanium	....	....	....	....	....	....	.....	*1*
Ficiomyia	....	....	....	....	....	....	.....	......
Ficus	1	....	....	....	....	....	.....	......

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Oligotrophiariae	*9*	*40*	*19*	*20*				
Phytophaga	*1*	*2*	*6*	*10*			*25*	
Agropyron			1					
Celtis			2					
Elymus				1				
Fraxinus			1					
Hordeum				1				
Picea		1						
Ribes			?1					
Salix		1		7				
Triticum				1				
Ulmus	1							
Viola	1		1					
Janetiella	*1*		*3*				*14*	
Castanea							1	
Chamaecyparis	1							
Myrica			1					
Pinus			1					
Vitis	1	2	1					
Oligotrophus	*1*	*2*	*1*				*6*	
Betula	1							
Juniperus		1						
Salix			1					
Solidago		1						
Rhopalomyia	*4*	*35*	*8*	*8*			*55*	
Antennaria		2						
Artemisia		5	1					
Aster	2		2					
Audibertia		?1						
Baccharis		2		1				
Bigelovia	1			1				
Castanea			1					
Chrysopsis		1						
Chrysothamnus		1		2				
Encelia				1				
Ericameria		1						
Erigeron		2						
Grindelia	1							
Gutierrezia		1						
Juniperus		1						
Ribes		1						
Sabina		1						
Salix		1						
Salvia			1					
Senecio		1						
Solidago		13	3	3				
Thuja		1						
Sackenomyia							*4*	
Salix				2				
Viburnum			1					
Walshomyia							*3*	
Juniperus	2	1						
Lasiopterariae	*4*	*6*	*50*	*68*				
Protaplonyx							*1*	
Sarcobatus			1					

Food habits of Itonid genera *(continued)*

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Aplonyx	....	....	....	....	....	....	*1*	......
Sarcobatus	....	....	1	....	....	....	.....	......
Lasioptera	*2*	*1*	*11*	*46*	....	....	*69*	......
Amphicarpa	....	....	....	1	....	....	.....	......
Angelica ?	....	....	....	1	....	....	.....	......
Aster	....	....	1	....	....	....	.....	......
Atriplex	....	....	....	1	....	....	.....	......
Benzoin	....	....	....	1	....	....	.....	......
Cassia	....	....	....	1	....	....	.....	......
Convolvulus	....	....	....	1	....	....	.....	......
Cornus	....	....	1	1	....	....	.....	......
Crataegus	....	....	1	....	....	....	.....	......
Danthonia	....	....	....	?4	....	....	.....	......
Desmodium	....	....	....	1	....	....	.....	......
Diervilla	....	....	....	1	....	....	.....	......
Diplacus	....	....	....	1	....	....	.....	......
Echinochloa	....	....	....	1	....	....	.....	......
Ephedra	....	....	....	2	....	....	.....	......
Fraxinus	....	....	1	....	....	....	.....	......
Galeopsis	....	....	....	1	....	....	.....	......
Helianthus	1	....	....	1	....	....	.....	......
Humulus	....	....	....	1	....	....	.....	......
Hypericum	....	....	....	1	....	....	.....	......
Impatiens	....	....	1	1	....	....	.....	......
Lactuca	....	....	....	1	....	....	.....	......
Lindera	....	....	....	1	....	....	.....	......
Lupinus	....	....	....	?1	....	....	.....	......
Lycopus	....	....	....	2	....	....	.....	......
Muhlenbergia	....	....	....	1	....	....	.....	......
Oxybaphus	....	....	....	1	....	....	.....	......
Panicum	....	....	....	2	....	....	.....	......
Pentstemon	....	1	....	1	....	....	.....	......
Piriqueta	....	....	....	1	....	....	.....	......
Portulaca	....	....	....	1	....	....	.....	......
Quercus	....	....	....	1	....	....	.....	......
Rubus	....	....	1	1	....	....	.....	......
Rudbeckia	....	....	....	?1	....	....	.....	......
Senecio	....	....	....	1	....	....	.....	......
Solidago	....	....	?1	2	....	....	.....	......
Spiraea	....	....	1	....	....	....	.....	......
Tripsacum	....	....	....	1	....	....	.....	......
Unknown	....	....	....	2	....	....	.....	......
Vaccinium	1	....	....	....	....	....	.....	......
Verbena	....	....	....	1	....	....	.....	......
Vernonia	....	....	1	1	....	....	.....	......
Vitis	....	....	2	....	....	....	.....	......
Zizia	....	....	....	1	....	....	.....	......
Neolasioptera	....	....	*2*	*20*	....	....	*38*	......
Ambrosia	....	....	....	1	....	....	.....	......
Asclepias	....	....	....	1	....	....	.....	......
Aster	....	....	....	1	....	....	.....	......
Clematis	....	....	1	....	....	....	.....	......
Cornus	....	....	....	1	....	....	.....	......
Desmodium	....	....	....	1	....	....	.....	......
Diplopappus	....	....	....	1	....	....	.....	......

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Eragrostis	....	....	....	?1	....	....	.....	......
Erigeron	....	....	....	1	....	....	.....	......
Eupatorium	....	....	....	2	....	....	.....	......
Gramineae	....	....	....	1	....	....	.....	......
Helianthus	....	....	....	2	....	....	.....	......
Hibiscus	....	....	....	1	....	....	.....	......
Mentha	....	....	....	1	....	....	.....	......
Mimulus	....	....	....	1	....	....	.....	......
Sambucus	....	....	....	1	....	....	.....	......
So'anum	....	....	....	1	....	....	.....	......
Unknown	....	....	....	1	....	....	.....	......
Viburnum	....	....	....	1	....	....	.....	......
Vitis	....	....	1	....	....	....	.....	......
Asteromyia	....	*2*	*31*	*2*	....	....	*31*	......
Aster	....	1	16	1	....	....	.....	......
Chrysothamnus	....	....	1	....	....	....	.....	......
Erigeron	....	....	1	....	....	....	.....	......
Grindelia	....	....	2	....	....	....	.....	......
Gutierrezia	....	....	1	....	....	....	.....	......
Hamamelis	....	....	1	....	....	....	.....	......
Muhlenbergia	....	....	....	1	....	....	.....	......
Solidago	....	1	8	....	....	....	.....	......
Vitis	....	....	1	....	....	....	.....	......
Clinorhyncha	....	....	....	....	....	....	*4*	......
Achillea	1	....	....	....	....	....	.....	......
Eupatorium	1	....	....	....	....	....	.....	......
Salix	....	....	?1	....	....	....	.....	......
Camptoneuromyia	....	....	....	....	....	....	*8*	......
Ipomoea	....	1	....	....	....	....	.....	......
Rubus	....	....	1	....	....	....	.....	......
Smilax	....	....	1	....	....	....	.....	......
Solidago	....	2	1	....	....	....	.....	......
Trotteria	....	....	....	....	....	....	*9*	......
Solidago	....	....	....	....	....	....	1	......
Thalictrum	....	....	....	....	....	....	1	......
Asphondylariae	*11*	*47*	*16*	*5*	....	....	.....	......
Schizomyia	*1*	*6*	....	....	....	....	*11*	......
Amsinckia	....	1	....	....	....	....	.....	......
Ipomoea	....	1	....	....	....	....	.....	......
Rivina	....	1	....	....	....	....	.....	......
Viburnum	....	1	....	....	....	....	.....	......
Vitis	....	2	....	....	....	....	.....	......
Asphondylia	*11*	*40*	*5*	*3*	....	....	*44*	......
Adenostoma	1	....	....	....	....	....	.....	......
Antennaria	....	1	....	....	....	....	.....	......
Artemisia	....	1	....	....	....	....	.....	......
Aster	....	1	....	....	....	....	.....	......
Atriplex	....	1	....	1	....	....	.....	......
Bigelovia	....	1	....	....	....	....	.....	......
Bumelia	....	?1	....	....	....	....	.....	......
Ceanothus	....	2	....	....	....	....	.....	......
Clerodendron	....	2	....	....	....	....	.....	......
Citharexylum	....	2	....	....	....	....	.....	......
Diervilla	....	2	....	....	....	....	.....	......
Diplacus	....	2	....	....	....	....	.....	......
Dondia	....	....	3	....	....	....	.....	......

Food Habits of Cecidomyia (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Encelia	....	2	....	....	....	....	.....	......
Eupatorium	1	....	....	1	....	....	.....	......
Garrya	....	1	....	....	....	....	.....	......
Helenium	....	2	....	....	....	....	.....	......
Helianthus	....	2	....	....	....	....	.....	......
Hydrangea	....	2	....	....	....	....	.....	......
Jussiaea	1	....	....	....	....	....	.....	......
Larrea	....	?2	....	....	....	....	.....	......
Medicago	1	....	....	....	....	....	.....	......
Mentzelia	....	1	....	....	....	....	.....	......
Nemopanthus	....	1	....	....	....	....	.....	......
Opuntia	2	....	?1	....	....	....	.....	......
Phyllanthus	1	....	....	....	....	....	.....	......
Prosopis	1	....	....	....	....	....	.....	......
Rhododendron	1	....	....	....	....	....	.....	......
Rhus	....	1	....	....	....	....	.....	......
Rudbeckia	....	1	....	....	....	....	.....	......
Salix	....	....	....	1	....	....	.....	......
Sambucus	....	1	....	....	....	....	.....	......
Sericocarpus	....	1	....	....	....	....	.....	......
Shepherdia	....	1	....	....	....	....	.....	......
Smilacina	1	....	....	....	....	....	.....	......
Solidago	....	3	1	....	....	....	.....	......
Spiraea	....	1	....	....	....	....	.....	......
Thalictrum	1	....	....	....	....	....	.....	......
Unknown	....	2	....	....	....	....	.....	......
Vernonia	....	1	....	....	....	....	.....	......
Cincticornia	....	....	....	....	....	....	*18*	......
Quercus	....	....	10	....	....	....	.....	......
Feltomyia	....	....	....	....	....	....	*3*	......
Pisonia	....	....	1	2	....	....	.....	......
Itonididinariae	*24*	*23*	*49*	*12*	*1*	*10*	.....	*71*
Erosomyia	....	....	..	....	....	....	*1*	......
Mangifera	....	....	1	....	....	....	.....	......
Toxomyia	....	....	....	....	....	....	*3*	......
Emilia	....	....	....	....	....	1	.....	......
Uromyces	....	....	....	....	....	1	.....	......
Lobopteromyia	....	....	....	....	....	....	*9*	......
Crataegus	....	....	1	....	....	....	.....	......
Endaphis	....	....	....	....	....	....	.....	*1*
Eriophyes	....	....	....	....	....	....	.....	1
Contarinia	*11*	*5*	*3*	....	....	....	*27*	......
Acer	....	....	1	....	....	....	.....	......
Agrimonia	1	....	....	....	....	....	.....	......
Clematis	....	1	....	....	....	....	.....	......
Cucumeris	....	1	....	....	....	....	.....	......
Eupatorium	1	....	....	....	....	....	.....	......
Fraxinus	....	....	1	....	....	....	.....	......
Gossypium	1	....	....	....	....	....	.....	......
Lycopersicum	1	....	....	....	....	....	.....	......
Negundo	....	....	1	....	....	....	.....	......
Pinus	....	2	....	....	....	....	.....	......
Prunus	1	....	....	....	....	....	.....	......
Pyrus	1	....	....	....	....	....	.....	......
Rumex	1	....	....	....	....	....	.....	......
Setaria	1	....	....	....	....	....	.....	......

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Sorghum	1	....	....	....	....	....	.....	......
Spiraea	....	1	....	....	....	....	.....	......
Tridens	1	....	....	....	....	....	.....	......
Vitis	1	....	....	....	....	....	.....	......
Thecodiplosis	*3*	*1*	*4*	*1*	....	....	*9*	......
Dulichium	1	....	....	....	....	....	.....	......
Liriodendron	....	....	1	....	....	....	.....	......
Pinus	....	....	2	....	....	....	.....	......
Quercus	....	....	1	....	....	....	.....	......
Secale	1	....	....	....	....	....	.....	......
Taxodium	....	....	....	1	....	....	.....	......
Triticum	1	....	....	....	....	....	.....	......
Zauschneria	....	1	....	....	....	....	.....	......
Dentifibula	....	....	....	....	....	....	*3*	......
Aspidiotus	....	....	....	....	....	....	.....	1
Pectinodiplosis	....	....	....	....	....	....	.....	*1*
Aphidoletes	....	....	....	....	....	....	.....	*11*
Aphids	....	....	....	....	....	....	.....	3
Bremia	....	....	....	....	....	*7*	.....	......
Youngomyia	....	....	....	....	....	....	*7*	......
Quercus	....	....	1	....	....	....	.....	......
Sambucus	....	1	....	....	....	....	.....	......
Vernonia	....	1	....	....	....	....	.....	......
Thomasia	....	....	....	....	....	....	*1*	......
Symphoricarpos	....	....	1	....	....	....	.....	......
Dicrodiplosis	....	....	....	....	....	....	.....	*14*
Coccid	....	....	....	....	....	....	.....	1
Crataegus	....	....	....	....	....	....	.....	1
Phenacoccus	....	....	....	....	....	....	.....	1
Pinus	....	....	....	....	....	....	.....	1
Populus	....	....	....	....	....	....	.....	2
Pseudococcus	....	....	....	....	....	....	.....	1
Quercus	....	....	....	....	....	....	.....	1
Kalodiplosis	....	....	....	....	....	....	*2*	......
Coccolobis	....	....	1	....	....	....	.....	......
Peridiplosis	....	....	....	....	....	....	*1*	......
Quercus	....	....	?1	....	....	....	.....	......
Lobodiplosis	....	....	....	....	....	....	.....	*8*
Dactylopius	....	....	....	....	....	....	.....	1
Quercus	....	....	....	....	....	....	.....	1
Coquillettomyia	....	....	....	....	....	....	.....	*5*
Feltiella	....	....	....	....	....	....	.....	*8*
Aphis	....	....	....	....	....	....	.....	1
Karschomyia	....	....	....	....	....	....	.....	*2*
Pseudococcus	....	....	....	....	....	....	.....	1
Clinodiplosis	....	....	....	....	....	....	*3*	......
Papaver	....	....	....	1	....	....	.....	......
Acaroletes	....	....	....	....	....	....	.....	*1*
Pseudococcus	....	....	....	....	....	....	.....	1
Mycodiplosis	....	....	....	....	....	....	.....	*38*
Aecidium	....	....	....	....	....	....	.....	1
Carya	....	....	....	....	....	....	.....	1
Corylus	....	....	....	....	....	....	.....	1
Cucurbita	....	....	....	....	....	....	.....	1
Lilium	....	....	....	....	....	....	.....	1

Food habits of Itonid genera (*continued*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Pinus	....	....	....	....	....	....	.....	1
Populus	....	....	....	....	....	....	.....	1
Prunus	....	....	....	....	....	....	.....	1
Pulvinaria	....	....	....	....	....	....	.....	2
Tetranychus	....	....	....	....	....	....	.....	3
Diadiplosis	....	....	....	....	....	....	.....	*5*
Coccid	....	....	....	....	....	....	.....	1
Pseudococcus	....	....	....	....	....	....	.....	2
Pulvinaria	....	....	....	....	....	....	.....	1
Saissetia	....	....	....	....	....	....	.....	1
Arthrocnodax	....	....	....	....	....	....	.....	*18*
Eriophyes	....	....	....	....	....	....	.....	1
Fungus	....	....	....	....	....	....	.....	1
Juniperus	....	....	....	....	....	....	.....	1
Prunus	....	....	....	....	....	....	.....	1
Sambucus	....	....	....	....	....	....	.....	1
Tetranychus	....	....	....	....	....	....	.....	4
Prodiplosis	....	....	....	....	....	....	*2*	......
Clematis	....	1	....	....	....	....	.....	......
Spiraea	....	1	....	....	....	....	.....	......
Triticum	1	....	....	....	....	....	.....	......
Caryomyia	....	....	....	....	....	....	*19*	......
Carya	1	....	18	....	....	....	.....	......
Giardomyia	....	....	....	....	....	....	*6*	......
Mentha	....	....	....	1	....	....	.....	......
Hyperdiplosis	*1*	*2*	*1*	....	....	*1*	*7*	......
Coffea	1	....	....	....	....	....	.....	......
Desmodium	....	1	....	....	....	....	.....	......
Eupatorium	....	....	1	....	....	....	.....	......
Ficus	....	....	....	....	....	....	1	......
Fungus	....	....	....	....	....	1	.....	......
Stachytarpha	....	1	....	....	....	....	.....	......
Epidiplosis	....	....	....	....	....	....	*1*	......
Metadiplosis	....	....	....	....	....	....	.....	*1*
Lestodiplosis	....	....	....	....	....	....	.....	*30*
Acer	....	....	....	....	....	....	.....	1
Apocynum	....	....	....	....	....	....	.....	1
Asclepias	....	....	....	....	....	....	.....	1
Betula	....	....	....	....	....	....	.....	1
Clematis	....	....	....	....	....	....	.....	1
Crataegus	....	....	....	....	....	....	.....	2
Eupatorium	....	....	....	....	....	....	.....	1
Fraxinus	....	....	....	....	....	....	.....	1
Hemichionaspis	....	....	....	....	....	....	.....	1
Phylloxera	....	....	....	....	....	....	.....	1
Platanus	....	....	....	....	....	....	.....	1
Populus	....	....	....	....	....	....	.....	2
Prunus	....	....	....	....	....	....	.....	1
Rumex	....	....	....	....	....	....	.....	1
Salix	....	....	....	....	....	....	.....	1
Scrophularia	....	....	....	....	....	....	.....	1
Solidago	....	....	....	....	....	....	.....	3
Spiraea	....	....	....	....	....	....	.....	1
Triticum	....	....	....	....	....	....	.....	1
Verbena	....	....	....	....	....	....	.....	1
Yucca	....	....	....	....	....	....	.....	1

Food habits of Itonid genera (*concluded*)

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Obolodiplosis	....	....	....	....	....	....	*1*	......
Robinia	....	....	1	....	....	....	.....	......
Retinodiplosis	....	....	....	....	....	....	*6*	......
Pinus	....	....	....	5	....	....	.....	......
Taxodium	1	....	....	....	....	....	.....	......
Parallelodiplosis	*1*	*1*	*2*	*1*	*1*	....	*16*	......
Carya	....	....	1	....	....	....	.....	......
Cattleya	....	....	....	....	1	....	.....	......
Prunus	1	....	....	....	....	....	.....	......
Quercus	....	....	....	1	....	....	.....	......
Spiraea	....	1	1	....	....	....	.....	......
Paradiplosis	....	....	....	....	....	....	*2*	......
Parthenium	....	....	1	....	....	....	.....	......
Itonida	*5*	*6*	*7*	*2*	....	....	*47*	......
Alopecurus	1	....	....	....	....	....	.....	......
Amelanchier	....	....	1	....	....	....	.....	......
Apocynum	....	1	....	....	....	....	.....	......
Betula	....	....	....	....	....	....	1	......
Castanea	....	....	....	....	....	....	.....	1
Catalpa	1	....	....	1	....	....	.....	......
Cornus	....	....	....	1	....	....	.....	......
Cucurbita	1	....	....	....	....	....	.....	......
Manihot	....	....	1	....	....	....	.....	......
Mentha	....	1	....	....	....	....	.....	......
Myrica	....	1	....	....	....	....	.....	......
Opuntia	....	....	1	....	....	....	.....	......
Prunus	1	....	....	....	....	....	.....	......
Pyrus	....	....	....	....	....	....	.....	1
Quercus	....	....	1	....	....	....	.....	1
Spiraea	....	2	....	....	....	....	.....	......
Taxodium	....	1	1	....	....	....	.....	......
Tecoma	....	....	1	....	....	....	.....	......
Triticum	1	....	....	....	....	....	.....	......
Verbena	....	....	1	....	....	....	.....	......
Hormomyia	....	....	....	....	....	....	*11*	......
? Cyperus	....	1	....	....	....	....	.....	......
Trishormomyia	....	*2*	*4*	....	....	....	*15*	......
Amelanchier	....	....	1	....	....	....	.....	......
Crataegus	....	....	1	....	....	....	.....	......
Helianthus	....	1	1	....	....	....	.....	......
Salix	....	....	1	....	....	....	.....	......
Spiraea	....	1	....	....	....	....	.....	......
Dyodiplosis	....	....	....	....	....	....	*1*	......
Odontodiplosis	....	....	....	....	....	....	*3*	......
Adiplosis	....	....	....	....	....	....	*1*	......
Monarthropalpus	....	....	....	....	....	....	*1*	......
Buxus	....	....	1	....	....	....	.....	......
Onodiplosis	....	....	....	....	....	....	*1*	......
Sarcobatus	....	1	....	....	....	....	.....	......
Cystodiplosis	....	....	....	....	....	....	*1*	......
Eugenia	....	....	1	....	....	....	.....	......
Astrodiplosis	....	....	....	....	....	....	*1*	......
Cissus	....	....	....	1	....	....	.....	......

Food Habits of Cecidomyia

Species which have not been reared.

PLANT GENERA	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagous
Abies	....	....	1	....	....	....	.....	......
Acalypha	....	1	....	....	....	....	.....	......
Acer	....	1	2	1	....	....	.....	......
Actinomeris	....	1	....	....	....	....	.....	......
Amelanchier	....	....	4	....	....	....	.....	......
Anthemis	....	1	....	....	....	....	.....	......
Arctium	1	....	....	....	....	....	.....	......
Aristolochia	....	....	1	....	....	....	.....	......
Artemisia	....	1	....	....	....	....	.....	......
Asclepias	....	....	2	....	....	....	.....	......
Atriplex	....	....	1	....	....	....	.....	......
Baccharis	....	....	....	2	....	....	.....	......
Benzoin	....	....	1	....	....	....	.....	......
Bidens	....	....	....	1	....	....	.....	......
Bigelovia	....	2	....	1	....	....	.....	......
Boehmeria	....	....	....	1	....	....	.....	......
Carpinus	....	....	1	....	....	....	.....	......
Carya	....	....	3	....	....	....	1	......
Castanea	1	....	3	....	....	....	.....	......
Ceanothus	....	....	1	....	....	....	.....	......
Celastrus	....	....	....	1	1	....	.....	......
Celtis	....	....	5	3	....	....	.....	......
Chamaecyparis	....	1	....	....	....	....	.....	......
Cicuta	....	....	1	....	....	....	.....	......
Cleome	1	....	....	....	....	....	.....	......
Collinsonia	....	....	2	....	....	....	.....	......
Cornus	....	....	1	1	....	....	.....	......
Corylus	....	1	....	....	....	....	.....	......
Crataegus	....	....	2	....	....	....	.....	......
Crotalaria	....	....	....	1	....	....	.....	......
Cystopteris	....	....	....	....	1	....	.....	......
Dioscorea	....	....	....	1	....	....	.....	......
Erechtites	....	....	....	1	....	....	.....	......
Eriogonum	....	1	....	....	....	....	.....	......
Eupatorium	....	....	1	....	....	....	.....	......
Euphorbia	1	....	....	....	....	....	.....	......
Fragaria	....	....	1	....	....	....	.....	......
Fraxinus	....	....	1	....	....	....	.....	......
Gaylussacia	....	....	1	....	....	....	.....	......
Geranium	....	....	....	....	....	1	.....	......
Gerardia	1	....	....	....	....	....	.....	......
Gnaphalium	1	....	....	....	....	....	.....	......
Gossypium	....	....	1	....	....	....	.....	......
Hamamelis	....	....	3	....	....	....	.....	......
Helenium	....	....	....	1	....	....	.....	......
Helianthus	....	....	....	1	....	....	.....	......
Hypericum	....	....	....	1	....	....	.....	......
Impatiens	....	1	....	....	....	....	.....	......
Juglans	....	....	1	....	....	....	.....	......
Juncus	?1	....	....	....	....	....	.....	......
Juniperus	....	1	1	....	....	....	.....	......
Kosteletzkya	....	....	....	1	....	....	.....	......
Laportea	....	1	....	1	....	....	.....	......

Food Habits of Cecidomyia (*concluded*)

Species which have not been reared.

TRIBE, GENUS AND PLANT	Fruit galls	Bud galls	Leaf galls	Stem galls	Root galls	Fungivorous	Phytophagous	Zoophagou
Lepachys	....	1	....	....	....	....	.....	......
Lespedeza	1	....	1	1	....	....	.....	......
Liriodendron	....	....	2	....	....	....	.....	......
Lonicera	....	1	....	....	....	....	.....	......
Lupinus	....	....	....	1	....	....	.....	......
Maianthemum	....	....	1	....	....	....	.....	......
Mentha	....	1	....	....	....	....	.....	......
Monarda	....	....	....	1	1	....	.....	......
Nyssa	....	....	1	1	....	....	.....	......
Oakesia	....	....	1	....	....	....	.....	......
Ostrya	....	....	2	....	....	....	.....	......
Pachistima	....	....	1	....	....	....	.....	......
Phleum	....	....	....	1	....	....	.....	......
Picea	....	....	1	....	....	....	.....	......
Pinus	....	1	1	....	....	....	.....	......
Polygonatum	....	....	1	....	....	....	.....	......
Populus	....	....	4	2	....	....	.....	......
Potentilla	....	....	....	1	....	....	.....	......
Prosopis	....	1	....	....	....	....	.....	......
Prunus	1	1	1	2	....	....	.....	......
Psedera	....	....	....	....	1	....	.....	......
Quercus	....	1	6	1	....	....	.....	......
Rhus	....	....	....	1	....	....	.....	......
Ribes	....	....	1	....	....	....	.....	......
Rubus	....	....	1	....	....	....	.....	......
Rudbeckia	....	1	....	1	....	....	.....	......
Salix	1	1	....	....	....	....	.....	......
Scirpus	....	....	....	?1	....	....	.....	......
Scutellaria	....	....	....	1	....	....	.....	......
Smilax	....	....	1	....	....	....	.....	......
Solidago	....	3	....	3	....	....	.....	......
Spiraea	....	2	1	....	....	....	.....	......
Symphoricarpos	....	....	....	1	....	....	.....	......
Taxodium	....	1	....	....	....	....	.....	......
Thermopsis	....	....	1	....	....	....	.....	......
Tilia	....	....	2	1	....	....	.....	......
Urtica	....	....	2	....	....	....	.....	......
Verbena	....	....	....	1	....	....	.....	......
Viburnum	....	....	4	....	....	....	.....	......
Vitis	....	....	4	....	....	....	.....	......
Totals	10	28	80	40	4	1	1	......

List of Species Not Referred to Genera, and of Galls from Which Adults Have Not Been Reared

The forms noticed below are listed alphabetically by their specific names. Several species very recently referred to modern genera are also included.

Cecidomyia amoyotii Fitch

1861 **Fitch, Asa.** N. Y. State Agric. Soc. Trans., 20:773–4
1865 ———— Nox. & Other Ins. N. Y., 6th Rep't, p. 31–2

This is probably a synonym of Thecodiplosis mosellana Gehin.

Cecidomyia angelicae Beutm.

1908 **Beutenmueller, William.** Can. Ent. 40:74

The gall, an elongate stem swelling, contains numerous larvae, on Angelica villosa. It is probably the work of a species of Lasioptera.

Cecidomyia annulipes Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:629
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8 2:746

Reared from the willow cone gall made by Rhabdophaga strobiloides Walsh and probably a species of Dasyneura.

Cecidomyia atricornis Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:628–9
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:746

Reared from the willow cone gall of Rhabdophaga strobiloides Walsh. Mycodiplosis alternata Felt may possibly be a synonym, since the coloration of the antennal segments is very similar, if not identical.

Asphondylia atriplicicola Ckll.

1898 **Cockerell, T. D. A.** Ann. Mag. of Nat. Hist., 7th ser., 2:326–7

An examination of the type female in the United States National Museum shows this is an Asphondylia. It may possibly be identical with A. atriplicis Ckll.

Cecidomyia atrocularis Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:626–8
1867 ———— Ent. Soc. Phil. Proc., 6:227–8
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:746

Reared from the willow cone gall of Rhabdophaga strobiloides Walsh. This is an Itonid and probably predaceous.

Cecidomyia balsamicola Lintn.

1888 **Lintner, J. A.** Inj. & Other Ins. N. Y., 4th Rep't, p. 60–3
1891 ———— Inj. & Other Ins. N. Y., 7th Rep't, p. 307–8
1908 **Jarvis, T. D.** Ent. Soc. Ont., 38th Rep't, p. 86
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 80
1912 **Cosens, A.** Canad. Inst. Trans. 9:317–18, Abies balsamea.

This insect deforms the balsam leaflets. It is widely distributed. The adult has not been reared.

Cecidomyia bedeguar Walsh

1868 **Walsh, B. D..** Can. Ent., 1:79–80
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:734
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 67
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 83
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 39

This is a subglobular, filamentous leaf gall occurring on Crataegus tomentosa.

Cecidomyia boehmeriae Beutm.

1908 **Beutenmueller, William.** Can. Ent., 40:74–5
1909 **Jarvis, T. D.** Ent. Soc. Ont., 39th Rep't, p. 80

The adult, probably a Lasioptera, is unknown. The larvae occur in fusiform stem swellings of nettle, Boehmeria.

Cecidomyia brachynteroides O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:198

This species produces a swelling at the base of scrub pine needles, Pinus inops. It is probably a species of Itonida and may be identical with I. pinirigidae Pack.

Cecidomyia brassicoides Town.

1893 **Townsend, C. H. T.** Psyche, 6:491

Reared from a budlike gall on Bigelovia and probably a species of Rhopalomyia.

Lestodiplosis caliptera Fitch

1845 **Fitch, Asa.** Am. Quar. Jour. Agric. & Sci., 2:261–3 (Diplosis)
1846 ———— N. Y. State Agric. Soc. Trans., 5:287–8
1865 ———— Nox. & Other Ins. N. Y., 6th Rep't, pl. II, fig. 18

An examination of two females received by Westwood from Fitch and now in the Hope collection at Oxford University, shows this species to be a Lestodiplosis. The specimens are in very poor condition.

Cecidomyia capsularis Patt.

1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 613
1897 **Patton, W. H.** Can. Ent., 29:248

This name is applied to one of several leaf galls occurring on hackberry.

Cecidomyia caryae O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. Amer. 1:191–2

The species was described by Osten Sacken as Diplosis caryae and supposed by him to have been the maker of the gall produced by the larva of Caryomyia caryae O. S. He in reality described two species, and we have retained the same specific designation for each, since they are referable to different genera. The Diplosis caryae of Osten Sacken is not identical with our Clinodiplosis caryae or Mycodiplosis holotricha, both probably inquilines in Caryomyia galls, as is probably true of the species under discussion.

Cecidomyia castaneae Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 17

This is an ellipsoidal, monothalamous gall occurring singly or in small groups near the base of chestnut leaves. It may prove identical with Rhopalomyia castaneae Felt.

Cecidomyia celastri Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 41

An irregular, subcortical enlargement of the roots of bittersweet, Celastrus scandens. Adult unknown.

Cecidomyia cerasiphila Felt

1911 **Felt, E. P.** Econ. Ent. Jour. 4:554

The female was reared February 21, 1887, by Mr Theodore Pergande of the Bureau of Entomology, from swollen fruits of wild cherry received the preceding June.

Cecidomyia chinquapin Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 389

The gall is an irregular swelling in the burrs of Chinquapin. The adult is unknown.

Cecidomyia citrina O. S.

1871 **Osten Sacken, C. R.** Amer. Ent. Soc. Trans. 3:53
1906 **Felt, E. P.** N. Y. State Mus. Mem. 8, 2:731
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 45

Swollen and deformed terminal twigs and leaves on Linden, Tilia americana, are not uncommon. The midge is unknown. The insect may prove to be Contarinia tiliarum Kieff. One large tree at Rhinebeck, N. Y., was so seriously affected that limbs died back for a distance of 4 or 5 feet. No larvae were found in the fall of 1906 or in July, 1907, although specimens examined in August contained small, yellowish larvae inhabiting oval cells usually just behind enlarged buds. None was found in the buds and it is presumable that the hypertrophy was due to irritation of adjacent tissues. The green tips of leaf petioles are somewhat enlarged in midsummer and on one side there may be an irregular mass of dead or dying, usually brown tissue, apparently the remains of aborted leaves.

A species of Torymus has been reared from this gall.

Gall. This is a swollen and deformed terminal bud or an enlargement of adjacent woody tissues. It is fleshy, moderately succulent, irregular in shape and frequently with rudimentary leaves.

Larva. Length .5 mm, reddish yellow, the head short, broad. Antennae slender, with a length fully 4 times the diameter. Body smooth, posterior extremity broadly rounded. The posterior spiracles are marked by chitinous, rounded tubercles. These larvae were taken from oval cells near the base of affected buds.

Full grown larva. Length 2.25 mm, yellowish, rather stout. Head rather small, triangular, the antennae stout, with a length 3 times the diameter; breastbone evident, bidentate, expanded apically, the shaft rather slender. Skin smooth, posterior extremity broadly rounded, with sublateral triangular, chitinous processes and posteriorly submedian conical processes, the posterior spiracles ending in elevated, slightly chitinized tubercles. These larvae were taken from affected twigs in February.

Cecidomyia clavula Beutm.

1913 **Beutenmuller, Wm.** Can. Ent. 45:416
1918 **Felt, E. P.** Am. Mus. Nat. Hist. Bul. 38:179

This is a Lestodiplosis probably predaceous on Lasioptera clavula Beutm., the latter described as Cecidomyia clavula in 1892.

Cecidomyia coccidarum Ckll.

1892 **Cockerell, T. D. A.** Entomologist, p. 181 (Diplosis)
1894 ——— Acad. Nat. Sci. Phil. Proc., p. 419 (Diplosis)
1900 **Coquillett, D. W.** U. S. Nat. Mus. Proc. 22:249–50
1914 **Felt, E. P.** Econ. Ent. Jour. 7:458

The type is said to be a female deposited in the British Museum of Natural History. Mr E. E. Austen under date of May 10, 1911, informed us that exuviae labeled as being this species protrude from the ovisac of Pulvinaria urbicola Ckll. and that there is nothing to show that the specimens are actually the types. The original description was drafted from a fresh specimen which emerged in a box containing leaves of Lignum vitae on which were species of Aleurodes and Aspidiotus aurantii Mask. and a young fruit of Anona infested by Pseudococcus virgatus Ckll. Three species of Trifila, (to which subtribe belongs a male in the British Museum labeled C. coccidarum) Lobodiplosis coccidarum Felt, Mycodiplosis coccidivora Felt and Dicrodiplosis coccidarum Felt have been reared from a very similar environment in that part of the world. Unfortunately, living or even dried pinned females in these genera present a very close superficial resemblance to each other, and there is nothing in the original description which enables us to establish even the generic identity of this West Indian species.

Cecidomyia collinsoniae Beutm.

1908 **Beutenmueller, William.** Can. Ent., 40:73–4
1909 **Jarvis, T. D.** Ent. Soc. Ont., 39th Rep't, p. 84

The gall is a green, onion-shaped, pubescent swelling on the underside of the leaves of horse-balm, Collinsonia canadensis.

Cecidomyia collinsonifolia Beutm.

1908 **Beutenmueller, William.** Can. Ent., 40:74

The gall is a pale green, elongate, narrow swelling on the underside of the midrib or larger veins of the leaf of the horse-balm, Collinsonia canadensis.

Cecidomyia coloradella Ckll.

1904 **Cockerell, T. D. A.** Can. Ent., 36:155

Reared from deformed flower heads of an undetermined species of Artemisia.

Cecidomyia cornu Walsh

1864 **Walsh, B. D.** Ent Soc. Phil. Proc., 3:590–91
1867 ———— Ent. Soc. Phil. Proc., 6:224
1909 **Brodie, William.** Can. Ent., 41:252

This gall appears to be but a modification, possibly due to parasitism of that made by the very common Phytophaga rigidae O. S.

Cecidomyia cossae Shim.

1869 **Shimer, Henry.** Am. Ent. Soc. Trans. 2:395
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:718

This insect was reared from hickory leaf galls and is probably a species of Lestodiplosis.

Cecidomyia crotalariae Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 40

The gall is a fusiform stem swelling on rattlebox, Crotalaria sagittalis.

Cecidomyia culmicola Morris

1850 **Morris, M. H.** Acad. Nat. Sci. Phil. Proc., 4:194
1862 **Harris, T. W.** Ins. Inj. to Veg., p. 582–3

This is probably a synonym of Phytophaga destructor Say, with which it is associated.

Lestodiplosis decemmaculata Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:631–3

This species was reared from the galls of Rhabdophaga strobiloides Walsh, Rock Island, Ill. Adults are said to agree in the ornamentation of the legs, almost exactly with C. maccus Loew.

Cecidomyia deserta Patt.

1897 **Patton, W. H.** Can. Ent., 29:247

This is an elongate stem gall on hackberry, possibly a species of Lasioptera.

Cecidomyia erigeroni Brodie

1894 **Brodie, William.** Biol. Rev. Ont., 1:13–15

The irregularly cylindrical galls of this species occur upon the base of the stems and the tips of the branches of the flowering panicles of Erigeron canadensis. The true maker of the gall is probably a species of Lasioptera.

Cecidomyia erubescens O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:200
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:619
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 21

This marginal leaf fold on oak is common and may possibly be made by one species, in which event Itonida foliora Rssl. & Hkr. becomes a synonym.

Cecidomyia eupatoriflorae Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 391

The gall is a deformed flower head and is green, succulent, pubescent and contains several larvae. Adult unknown.

Cecidomyia frater Ckll.

1890 **Cockerell, T. D. A.** Entomologist, p. 280–81

This insect was reared from the willow cabbage gall of Rhabdophaga brassicoides Walsh and is an inquiline, possibly referable to Rhopalomyia.

Cecidomyia fulva Beutm.

1908 **Beutenmueller, William.** Can. Ent., 40:75
1909 **Jarvis, T. D.** Ent. Soc. Ont., 39th Rep't, p. 90
1911 **Felt, E. P.,** Econ. Ent. Jour. 4:462

The gall is a globular, succulent swelling on the stem, petiole or leaf of the balsam, Impatiens fulva.

Asphondylia garryae O. S.

A suboval, irregular, black swelling on Garrya fremontii taken at Yosemite, Calif., elevation 7000 feet, June 1876, is thus labeled in the United States National Museum collection.

Cecidomyia gaylussacii n. nom.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:196

This is a valvular swelling arising from the midrib of the Vaccinium leaf and much resembling an oyster attached by its hinge. This may be the work of a species of Dasyneura.

Cecidomyia gemmaria Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 53

This is a one celled, ovate, pubescent bud gall on aster and may prove to be that of Rhopalomyia lateriflori Felt.

Rhabdophaga gnaphaloides Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:583–85
1867 ————. Ent. Soc. Phil. Proc., 6:223–4
1890 **Wheeler, W. M.** Insect Life, 2:223
1893 ———— Jour. Morphol., 8:3
1906 **Felt, E. P.** Ins. Affect. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8 2:745
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul 2, p. 11

The gall is a small, ovate bud deformity, the female differing from that of R. brassicoides according to Walsh, only on account of its small size.

Lestodiplosis graminis Fitch.

1846 **Fitch, Asa.** N. Y. State Agric. Soc. Trans., 5:285–7
1865 ———— Nox. & Other Ins. N. Y., 6th Rep't, p. 90–1

This appears to be a predaceous enemy of the wheat midge, Thecodiplosis mosellana Gehin.

Cecidomyia grossulariae Fitch

1855 **Fitch, Asa.** N. Y. State Agric. Soc. Trans. 14:880
1856 ———— Nox. Ins. N. Y. 1st–2d Rep't, p. 176
1859 ———— Nox. Ins. N. Y. 3d Rep't, p. 119
1869 **Packard, A. S.** Guide Study Ins. p. 376

This midge was reared by Doctor Fitch from putrid gooseberries infested by small, bright yellow, oval maggots. He states that this species breeds equally well in wild gooseberries. It has been referred to the genus Dasyneura, evidently because the original description gives the number of antennal segments as twelve, the fact that Doctor Fitch habitually overlooked the first two segments apparently being ignored. The distinctly stemmed flagellate segments prevent the reference of the species to Dasyneura; neither can it be referred to the Cecidomyia ribesii Meign., a species of Asphondylia, although it was compared therewith by Doctor Fitch. It may belong to Contarinia.

Cecidomyia hageni Aldr.

1881 **Hagen, H. A.** Can. Ent. 13:37

The above name was proposed by Aldrich in his catalog for an oval, rounded gall described by Hagen, on the underside of Aristolochia leaves.

Cecidomyia hopkinsi Felt

1911 **Felt, E. P.** Econ. Ent. Jour. 4:554-55

This rather large, reddish brown midge can hardly be a Lestodiplosis because of the peculiar spotting of the wings, and may be easily recognized by the yellow banded legs. It was reared in May 1899 from Scolytid burrows in Pinus attenuata collected by Dr A. D. Hopkins at San Francisco, Calif.

Cecidomyia impatientis O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A. 1:204
1869 **Walsh, B. D.** Am. Ent. 2:63
1874 **Glover, Townend.** MS. Notes My Jour. Dipt., pl. 11, fig. 16
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul. 4, p. 269
1904 **Cook, M. T.** Ohio State Univ. Bul. 8, 13:140
1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23:392-93
1907 **Cook, M. T.** Acad. Sci. Proc., Sep., p. 9
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 43
1912 **Cosens, A.** Can. Inst. Trans. 9:319-20

The gall was first briefly described by Osten Sacken in 1862, and in 1869 Walsh figured it and gave a more detailed account, illustrating the breastbone of the larva.

The green, nearly globular gall, about one-half an inch in diameter, occurs in September and is then a succulent swelling at the base of the flower of Impatiens fulva. It contains numerous cells and the larvae have an almost clove-shaped breastbone.

Cecidomyia inimica Fitch

1861 **Fitch, Asa.** N. Y. State Agric. Soc. Trans., 20:831-2
1865 ———— Nox. & Other Ins. N. Y., 6th Rep't, p. 88-90

This species was observed by Doctor Fitch in wheat fields infested with the wheat midge, Thecodiplosis mosellana Gehin.

Cecidomyia irregularis Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 9

This insect inhabits an irregular, monothalamous blister gall occurring between the veins of the large toothed Aspen, Populus grandidentata.

Cecidomyia lappa Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 35

A terminal brown or green, mossy bud gall on Spiraea salicifolia and resembling that of Rhodites rosae though coarser.

Cecidomyia maccus Loew.

1862 **Loew, Hermann.** Mon. Dipt. N. A., 1:187–8

This is a strongly marked species. Mycodiplosis alternata Felt may prove to be a synonym.

Cecidomyia majalis O. S.

1870 **Osten Sacken, C. R.** Am. Ent. Soc. Trans., 3:53–4, 347
1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 207–8
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:710
1907 **Jarvis, T. D.** 37th Rep't Ent. Soc. Ont., p. 68
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 17, 21, 22, 24
1912 **Cosens, A.** Can. Inst. Trans. 9:320

The gall occurs along the midrib, is thin-walled, more or less wrinkled and with a slit which opens readily and allows the larva to escape. Clinodiplosis florida Felt may prove to be a synonym.

Dasyneura meibomiae Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. Vol. 23:390 (Cecidomyia)
1913 ——————— Can. Ent. 45:415–16 (Cecidomyia)
1918 **Felt, E. P.** Am. Mus. Nat. Hist. Bul. 38:180

The gall is an elongate, fusiform, clustered bud growth occurring on several species of tick-trefoil, Desmodium species.

Cecidomyia monardae Brodie

1894 **Brodie, William.** Biol. Rev. of Ont., 1:109–11
1907 **Cook, M. T.** Ia. Acad. Sci. Proc., Sep., p. 9–10

This is an obscure stem gall on the flowering branches of Monarda fistulosa, probably made by a species of Lasioptera.

Cecidomyia muscosa Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 35

This is a subglobular, mossy, filamentous leaf gall on blackberry, Rubus nigrobaccus.

Cecidomyia negundinis Gill.

1890 **Gillette, C. P.** Psyche, 5:392–3
1904 **Washburn, F. L.** Minn. Agric. Exp't Sta. Bul. 88, p. 185–6
1905 ———— Minn. Agric. Exp't Sta. Bul. 93, p. 66
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:728
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 67
1909 **Felt, E. P.** Ent. Soc. Ont., 39th Rep't, p. 43
1909 **Jarvis, T. D.** Ent. Soc. Ont., 39th Rep't, p. 85

This species inhabits the terminal buds of the box elder, Acer negundo. Contarinia negundifolia Felt may possibly be a synonym.

Cecidomyia niveipila O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:199–200
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul., 4, p. 271
1904 ———— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 31
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem 8, 2:710
1907 **Jarvis, T. D.** Ent. Soc. Ont, 37th Rep't, p. 66
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 86
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 17

Oak leaves with a greatly swollen midrib, the sides of the gall margined with a white pubescence, are rather common. This insect has not been reared. It may be a species of Dasyneura.

Cecidomyia nyssaecola Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p 387–8
1918 **Felt, E. P.** Am. Mus. Nat. Hist. Bul. 38, p. 179–80

The gall is a narrow marginal leaf fold on sour gum, Nyssa sylvatica, somewhat resembling that of Itonida foliora Rssl. & Hkr. on oak.

Cecidomyia ocellaris O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:199
1874 **Glover, Townend.** MS. Notes My Jour. Dipt., pl. 9, fig. 29
1882 **Comstock, J. H.** U. S. Com. Agric. Rep't, p. 202–4
1883 **Mik, Joseph.** Verh. Zool.-Bot. Ges. Wien., 33:190–92
1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 411
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul. 4, p. 273
1904 ———— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 33
1905 **Cook, M. T.** Dep't Geol. & Nat. Res. Ins., 29th Rep't, p. 843
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:619; 629–30
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 66
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 42
1912 **Cosens, A.** Can. Inst. Trans., 9:320–21
1912 **Felt E. P.** N. Y. Ent. Soc. Jour., 20:248

The circular, yellow and red margined discolorations on soft maple leaves produced by this widely distributed insect are very common. Repeated efforts to obtain adults have been unsuccessful.

Cecidomyia orbitalis Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:623
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:746

This appears to be a rather common inquiline in the galls of Rhabdophaga batatas Walsh, R. strobiloides Walsh and R. brassicoides Walsh. It is probably referable to the genus Dasyneura.

Cecidomyia oviformis Patt.

1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 612
1897 **Patton, W. H.** Can. Ent., 29:248

This is a subglobular twig or petiole gall on hackberry, Celtis.

Cecidomyia palmeri Ckll.

1902 **Cockerell, T. D. A.** Can. Ent., 34:184

This is a manuscript name proposed by Professor Cockerell for a gall in the dry stems of Amaranthus palmeri, the larva of which is briefly described as a Cecidomyia species. Probably a species of Lasioptera.

Cecidomyia pellex O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:199
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul. 4, p. 265
1904 ———— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 26
1904 **Cook, M. T.** Ohio St. Univ. Bul. 8, 13:140
1905 ———— Dep't Geol. Nat. Res. Ind., 29th Rep't, p. 838
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:620; 632–3
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 67
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 76
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 47
1912 **Cosens, A.** Can. Inst. Trans., 9:321

This name has generally been applied to a reddish brown, elongate, fleshy midrib gall on the leaflets of the American ash. Type galls in the Museum of Comparative Zoology at Cambridge, Mass., are about 1–8 of an inch long, subglobular and protruding above or below the leaf a distance nearly equal to its diameter. The insect has not been reared. Breeding jars containing the larger, more conspicuous form mentioned above, has produced two midges, namely, Dasyneura tumidosae Felt and Contarinia canadensis Felt. It is probable that one, possibly both, of these may be the true gall maker.

Cecidomyia peritomatis Ckll.

1913 **Cockerell, T. D. A.** Econ. Ent. Jour., 6:279–80

This insect produced a more or less claviform or variously enlarged pod on stinking clover, Cleome serrulata. The orange colored larvae occur in great numbers in the seed pods.

Cecidomyia pictipes Will.

1896 **Williston, S. W.** Ent. Soc. Lond. Trans., p. 253

This species was described by Professor Williston from four specimens taken at St Vincent, W. I.

Cecidomyia pinirigidae Pack.

1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 798–800
1903 **Felt, E. P.** Forest, Fish & Game Com., 7th Rep't, p. 510–11
1906 ———— Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:423–25; figured in v. 1, pl. 20, fig. 4

The shortened, deformed pine needles with a swollen base, produced by this species, are rather common. We are not certain that the true gall maker has been reared, although Doctor Packard describes a midge as having been obtained from this deformity. The true gall maker is probably as pecies of Retinodiplosis. The parasite, Polygnotus species, has been reared from this gall.

Cecidomyia poculum O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:201
1874 **Glover, Townend.** MS. Notes My Jour. Dipt., plate 9, fig. 27
1892 **Beutenmueller, William** Am. Mus. Nat. Hist. Bul. 4, p. 271
1904 ———— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 30–1
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 69
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 86
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 27
1910 **Cook, M. T.** Mich. Geol. & Biol. Surv., Pub. 1, Biol. ser. 1, p. 31

The galls are small, circular, flat scales less than 1–4 of an inch in diameter, varying from a pale to a bright vivid rose red-color and attached to the leaf by a slender foot-stalk. They occur on the post oak, Quercus obtusiloba. A very similar deformity produces a Cynipid. The types of this gall are in the Museum of Comparative Zoology at Cambridge, Mass.

Cecidomyia potentillaecaulis Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 37

This gall is a much enlarged unilocular, internodal stem gall on Cinquefoil, Potentilla canadensis.

Cecidomyia pubescens Patt.

1890 **Packard A. S.** U. S. Ent. Com., 5th Rep't, p. 613
1897 **Patton, W. H.** Can. Ent., 29:248 (Name proposed)

This leaf gall on Celtis closely resembles that produced by Pachypsylla celtidis-pubescens, although it is much larger, more globular and at once recognized by the absence of a depression on the upper surface of the leaf.

Cecidomyia pudibunda O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:202
1906 **Felt, E. P.** Ins. Affec. Pk. & Wld. Trees, N. Y. State Mus. Mem. 8, 2:722
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 66
1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 389
1909 **Jarvis, T. D.** Ent. Soc. Ont., 39th Rep't, p. 77
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 15

This gall is a lateral leaf fold, tinged with red on the outside, on hornbeam, Carpinus americana. The larva in June is very small and whitish. The type of this gall is in the Museum of Comparative Zoology, Cambridge, Mass. This species may be identical with Contarinia carpini Kieff., since the galls are very similar.

Cecidomyia q-oruca Walsh

An elongate fold gall close to the midrib, some 12 mm long, 1 mm wide, irregularly annulate and containing white larvae, occurs on Quercus tinctoria and is labeled as this species in the Museum of Comparative Zoology, Cambridge, Mass.

Cecidomyia racemi Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 39

This is an elliptical, polythalamous gall on the axis of chokecherry, Prunus virginiana racemes. It is green, turning brown on maturing and is irregularly traversed by larval borings.

Cecidomyia reniformis Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 36

This is a polythalamous, somewhat reniform gall attached by the end or side to the base of a petiole of strawberry, Fragaria virginiana. It is 8 to 21 mm long and 11 to 20 mm thick.

Cecidomyia rudbeckiae Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 388
1918 **Felt, E. P.** Am. Mus. Nat. Hist. Bul. 38, p. 179

This insect is associated with a deformation and enlargement of the florets of the cone flower, Rudbeckia hirta, sometimes including those of the entire head. It is a species of Lestodiplosis.

Cecidomyia semenrumicis Patt.

1890 **Packard, A. S.** U. S. Ent. Com., 5th Rep't, p. 613
1897 **Patton, W. H.** Can. Ent., 29:248

This gall is a unilocular, achene-like swelling on the twig or leaf of hackberry, Celtis species.

Lestodiplosis septemmaculata Walsh

1864 **Walsh B. D.** Ent. Soc. Phil. Proc., 3:630

This species was reared by Walsh from the galls of Rhabdophaga brassicoides.

Cecidomyia serotinae O. S.

1871 **Osten Sacken, C. R.** Am. Ent. Soc. Trans., 3:346
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul. 4, p. 265
1904 ———— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 25–6
1905 **Cook, M. T.** Dep't Geol. & Nat. Res. Ind., 29th Rep't, p 838
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:733
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 66
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 89
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 40

The gall, sometimes the size of a cherry and red, is a rather common enlargement of the terminal buds on young shoots of wild cherry, Prunus serotina. Within there are a number of bright yellowish or reddish larvae. This species has not been reared.

Cecidomyia spiniformis Patt.

1890 **Packard, A S.** U. S. Ent. Com., 5th Rep't, p. 614
1897 **Patton, W. H.** Can. Ent., 29:248 (Name proposed)

This leaf gall on hackberry, Celtis, is a cylindrical enlargement' slightly narrowed at the base, truncate apically and with a median nipple.

Dasyneura spongivora Walk.

1878 **Osten Sacken, C. R.** Cat. Dipt., p. 4

This species has been listed from Martin Falls, Canada, by Francis Walker and doubtfully referred to this genus by Kertesz.

Cecidomyia squamulicola Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 16

This species deforms the base of sterile catkins of hazel, Corylus americana.

Rhabdophaga strobiliscus Walsh

1864 **Walsh, B. D.** Ent. Soc. Phil. Proc., 3:582–3 (Cecidomyia)
1867 ——— Ent. Soc. Phil. Proc., 6:223 (Cecidomyia)
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8, 2:745, 746

This gall may prove to be but an abnormal form of Rhabdophaga strobiloides O. S.

Dasyneura strobiloides Town.

1894 **Townsend, C. H. T.** Psyche, 7:176

The insect produces a conelike gall on Bigelovia graveolens in New Mexico. There is a fair probability of its being a species of Rhopalomyia. A parasite, Torymus species, has been reared from this gall.

Cecidomyia tergata Fitch

1845 **Fitch, Asa.** Am. Quar. Journ. Agric. & Sci., 2:264
1846 ——— N. Y. St. Agric. Soc. Trans., 5:288

Doctor Fitch states that this is a much more abundant form than the closely related C. thoracica.

Cecidomyia thoracica Fitch

1845 **Fitch, Asa.** Am. Quar. Jour. Agric. & Sci., 2:263–4
1846 ——— N. Y. State Agric. Soc. Trans., 5:288

The description is too brief to permit an identification.

Cecidomyia thurstoni Brodie

1894 **Brodie, William.** Biol. Rev. of Ont., 1:73–5

This is a stem gall on Helianthus divaricatus, very probably made by a species of Lasioptera.

Cecidomyia torreyi Ckll.

The female so labeled, probably a species of Rhopalomyia, is in the National Museum and is verv incompletely described as Cecidomyia n. sp. in Can. Ent. 34:184, 1902.

Cecidomyia ? triadenii Beutm.

1908 **Beutenmueller, William.** Can. Ent., 40:74

The gall is green, globular, somewhat elongated and occurs on the stalk of Marsh St John's-wort, Triadenum virginicum. It is probably a synonym of Lasioptera palustris Felt.

Cecidomyia tuba Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 46

The gall is a slender tube 10 to 16 mm long, 1.5 to 2 mm in diameter and somewhat larger at the base than at the tip. It has been recorded from Springfield, Mass., on Cornus amomum, has been received from Michigan and occurs in the vicinity of Albany. We have reared a parasite, Torymus ostensackenii D. T. from this gall.

Cecidomyia unguicula Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 388
1918 **Felt, E. P.** Am. Mus. Nat. Hist. Bul. 38, p. 180

This gall is somewhat the shape of a small carpet tack, is monothalamous and occurs in clusters on the underside of the leaf of hackberry, Celtis occidentalis. This is possibly a species of Dasyneura.

Cecidomyia urnicola O. S.

1875 **Osten Sacken, C. R.** Can. Ent., 7:202
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 66
1909 ———— Ent. Soc. Ont., 39th Rep't, p. 92

The urn-shaped, subsessile, pale green, semitransparent, succulent galls are about 3 mm high and occur on the upper surface of the leaves of Urtica gracilis.

Cecidomyia venae Stebb.

1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 39

An irregularly oval, fleshy gall on the midribs or chief veins of Crataegus. These galls occur on either surface and open by a slit on the opposite side. They are clear yellowish, sometimes with a reddish tinge. This is probably Lobopteromyia venae Felt.

Cecidomyia verbesinae Beutm.

1907 **Beutenmueller, William.** Amer. Mus. Nat. Hist. Bul. 23, p. 391

The galls are budlike, rounded, obtuse, usually unilocular or sometimes flattened and occur on the flower heads of Verbesina alternifolia. Polygnotus actinomeridis Ashm. MS (Insect Life 4: 126) was apparently reared from this gall.

Cecidomyia verrucicola O. S.

1875 **Osten Sacken, C. R.** Can. Ent., 7:201–2
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul., 4:264
1902 **Cook, M. T.** Ohio St. Univ. Bul. 15, ser. 6 (Cecidomyia)
1903 ——— Ohio St. Univ. Bul., ser. 7, no. 20, p. 427
1904 **Beutenmueller, William.** Am. Mus. Nat. Hist. Guide Leaflet 16, p. 24–5
1904 **Gibson, Arthur.** Ent. Soc. Ont., 34th Rep't, p. 59
1905 **Cook, M. T.** Dep't Geol. & Nat. Res. Ind., 29th Rep't, p. 838
1906 **Felt, E. P.** Ins. Affec. Pk. & Wdld. Trees, N. Y. State Mus. Mem. 8 2:620, 631
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 67
1909 ——— Ent. Soc. Ont., 39th Rep't, p. 77
1910 **Stebbins, F. A.** Springf. Mus. Nat. Hist. Bul. 2, p. 45
1910 **Cook, M. T.** Mich. Geol. & Biol. Surv., Pub. 1, Biol. ser. 1, p. 31

This is a bud-shaped, green or brown gall frequently very abundant upon the leaves of Linden, Tilia and showing about equally on both sides. It is widely distributed and though common, the adults do not appear to have been reared. The gall may be produced by a species of Hormomyia.

Cecidomyia viticola O. S.

1862 **Osten Sacken, C. R.** Mon. Dipt. N. A., 1:202
1869 **Walsh, B. D. & Riley, C. V.** Am. Ent., 2:28, 113 (C. lituus Walsh, MS)
1873 **Riley, C. V.** Nox. & Other Ins. Mo., 5th Rep't, p. 118–9
1883–9 **Saunders, William.** Ins. Inj. to Fruits, p. 292
1892 **Beutenmueller, William.** Am. Mus. Nat. Hist. Bul. 4, p. 272
1904 ——— Am. Mus. Nat. Hist. Guide Leaflet 16, p. 32
1904 **Cook, M. T.** Ohio St. Univ. Bul. 8, 13:141
1907 ——— Acad. Sci. Proc., Sep., p. 8, 9
1907 **Jarvis, T. D.** Ent. Soc. Ont., 37th Rep't, p. 67
1909 ——— Ent. Soc. Ont., 39th Rep't, p. 82
1914 **Felt, E. P.** Econ. Ent. Jour., 7:339 (larva described)

The gall is elongate, conical, reddish or green $\frac{1}{4}$ to $\frac{1}{3}$ of an inch long and occurs on the upper surface of the leaves of grape, Vitis species. The adult is unknown. Cecidomyia lituus Walsh, MS is identical.

BIOLOGY

The study of the biology of gall midges is not easy since, owing to their small size, it is difficult to detect them in nature except under the most favorable conditions; even then one must be prepared for a close resemblance; for example, two apparently identical forms may belong to different genera.

Hibernation. Most gall midges appear to winter as larvae or pupae. There is evidence to show that under exceptional circumstances it is possible that midges of Contarinia sorghicola Coq. may hibernate. It may be stated as a general rule that stem-inhabiting species, such as Rhabdophaga and Sackenomyia in Salix and Lasioptera in Solidago and Aster, winter in the food plant. It may be noted in passing that the adults of those forms inhabiting stems of herbaceous plants and most if not all of those wintering in willow shoots emerge in early spring, while a number of species of Lasioptera and its allies, found in subcortical galls of shrubs, such as Lasioptera linderae Beutm. on benzoin or spice-bush, and Neolasioptera sambuci Felt on Sambucus, do not attain maturity till some time in early summer. A number of other species winter in the galls and appear in early spring, such as Caryomyia, Cincticornia and some species of Asteromyia. Cincticornia pilulae Walsh, and possibly other members of the same genus, desert the galls in the spring just prior to pupation, enter the soil and in about ten days appear as adults. This is not true of the other genera mentioned above, since the midges emerge direct from the galls. Many species winter as larvae in the earth, such as Contarinia pyrivora Riley, C. johnsoni Sling., many species of Dasyneura and presumably most forms living in galls composed of the more tender and therefore easily destroyed tissues.

Number of generations. It is probable that most species produce but one generation annually. This is true of Contarinia johnsoni Sling., the species of Rhabdophaga, Sackenomyia and Lasioptera occurring in plant stems, the various species of Caryomyia and Cincticornia and probably many others. Certain forms, such as Diarthronomyia hypogea F. Lw., Contarinia sorghicola Coq., Phytophaga destructor Say and P. violicola Coq., appear to breed throughout a large portion of the season as long as the food plant affords suitable conditions. There is probably more than one generation of Asphondylia monacha O. S. since adults may be observed abroad from June till September or into October. There is presumably but one generation annually of Schizomyia pomum Walsh & Riley.

Habits of the adult. Some species belonging to this family of delicate flies may be observed abroad throughout a greater part of the growing season. They are to be found mostly in quiet, sheltered situations, such as to the leeward of a clump of bushes, a wall, a building or even upon the window. We have repeatedly taken Dirhiza hamata Felt on a window three stories from the ground, while Kieffer records the capture of Hormomyia at a window in the second story of the college at Bitch, Germany. He states that even the heavy Mikiola fagi Hart. may oviposit near the top of large beech trees. We have noted several instances where the female of Caryomyia tubicola O. S. evidently displayed a marked preference for a sheltered bud when depositing her eggs. Asphondylia monacha O. S. is a moderately strong flyer in nature.

A number of species of gall midges have been observed upon spider webs, occasionally in such numbers as to adorn a considerable proportion of the threads with series of somewhat evenly spaced midges. The tiny insects evidently find attractive resting conditions on the rather sheltered webs, supports admirably adapted to the easy, hanging position favored by these midges. Several American and African midges have been captured on spiders webs, some at least appearing entirely at home when hanging from the web and frequently returning to these delicate supports.[1]

Kieffer states that one rarely observes Cecidomyias taking nourishment, though some species of Lasioptera, Clinorhyncha and certain Lestremiinae may forage on the flowers of Umbelliferae. Campylomyza pomoflorae Felt occurs rather commonly in May, flying about the flowers of shadbush, Amelanchier canadensis, and also on the flowers of wild cherry, Prunus pennsylvanica. The duration of the adult existence must be extremely short in some instances at least. Diarthronomyia hypogea F. Lw. emerges in the early morning hours. The males live about 12 hours and the females 2 or 3 days. It is stated that the life in confinement of the male and female of Contarinia sorghicola Coq. is approximately 24 hours, while females, when allowed to oviposit, generally live about 2 days. The close limitation of Contarinia johnsoni Sling. to the vineyard and the deposition of the eggs within a short time indicate a brief existence for the adult. The period of activity of forms presumably depositing eggs in buds of oak and hickory, namely, species of Cincticornia and Caryomyia, must likewise be quite restricted, since these buds open very rapidly in the spring. On the other hand, it is probable that Asphondylia monacha O. S., with a continuous crop of buds developing upon various species of Solidago and Aster, has a somewhat extended existence, especially as but one egg is usually deposited in a bud. Pairing in some species, as Contarinia sorghicola Coq., may occur even before the females have dried and oviposition commence as soon as flight is possible.

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[1] 1912 N. Y. Ent. Soc. Jour., 20:147; 1920 Ann. Natal Mus. 4:494, 495; 1921 Ent. Soc. Lond. Trans., pts. 3 & 4, p. 443.

The persistence of these insects in a locality with but a limited food supply is well shown by the occurrence of Cecidomyia venae Steb. galls on a small Crataegus bush at Nassau for at least 4 years, although it was not seen anywhere else within 5 miles of the favored shrub.

Oviposition. The deposition of eggs by midges has been observed in a number of species. The eggs are frequently placed in positions where the larvae will find abundant sustenance and in other cases are deposited near a food supply. This latter is true, for example, of Phytophaga destructor Say, a species which places its eggs upon the leaves, while the larvae develop between the base of the leaf sheath and the stem. The European Mikiola fagi Hart., according to Kieffer, lays its eggs on the buds of beech or on the bark immediately below, compelling the young maggots to penetrate between the bud scales before establishing themselves. This method of oviposition is probably true also of a number of species of Caryomyia and Cincticornia. Contarinia sorghicola Coq., deposits its eggs within the seed, a process described by Mr Dean as follows:

> When the female has selected the seed she takes up a position on the apex, her abdomen elevated slightly above the tip, and immediately extends her ovipositor, pushing it within the seed until it is fully extended; then, with a rapid pistonlike motion, she places the egg. It is doubtful if more than one egg is deposited by a single female in the same seed.

It is probable that Contarinia johnsoni Sling. deposits its eggs within the blossom buds of grape, one to as many as fifteen maggots being found within a single bud. The duration of this stage is brief, perhaps but a day or two in this species. The egg period for C. sorghicola Coq. has been established at from 2 to 4 days. Dasyneura leguminicola Lintn. has a long, threadlike ovipositor. The deposition of the eggs has been described by Doctor Folsom as follows:

> Standing on the outside of a green cloverhead, the female inserts this organ [ovipositor] among the florets and works it deeper and deeper until it can go no farther. The sensitive tip of the sinuous ovipositor finds a suitable spot for an egg and the female becomes quiet until the egg is laid. The entire process of egg-laying requires usually 5 minutes, and often 10 to 15 minutes. Though the same female may lay several eggs in one cloverhead, she appears to make it a rule to distribute her eggs among a good many plants. Many females may, of course, oviposit in the same head, with the result sometimes that more larvae hatch than can possibly find food. Thus in one head of eighty florets the writer found 106 eggs. Once in a while an egg is laid on a petal or on the calyx itself, but almost always it is glued to one of the hairs of the immature calyx, the glue often forming quite a perceptible mass.

Diarthronomyia hypogaea F. Lw. deposits its eggs among the plant hairs on the leaves and young stems, the number deposited from time to time varying from 5 to 135, the number for each female ranging from 5 to 150 (Guyton). We have found as many as sixty larvae in the large midrib swelling on ash leaves produced by Contarinia canadensis Felt, the eggs from which they came probably having been deposited by one female. Certain species exhibit excellent selective powers. The European Xylodiplosis nigritarsis Zett., according to Kieffer, returns in numbers to the surface of split oak wood in the forest for the purpose of depositing eggs but never alights upon the adjacent beech wood. The females of Endaphis perfidus, Kieff., according to the observations of its describer, oviposit on the bodies of aphids, though he has never seen them lay eggs on the foliage infested by the insect host.

The majority of the female midges have ovipositors structurally incapable of piercing vegetable tissues, marked exceptions being the genera Asphondylia, Schizomyia, Sackenomyia and Monarthropalpus. The highly specialized, aciculate terminal portion of the ovipositor in Asphondylia appears to be admirably adapted to piercing the floral organs or tender leaf tissues. Schizomyia has a less specialized structure and it is presumably not so efficient as an organ of penetration. The ovipositor in the larger species of Sackenomyia is acute, heavily chitinized and appears admirably adapted for penetrating cortical tissues. The smaller species represented by

S. viburnifolia Felt have rather strongly chitinized, short, curved ovipositors similar to that of Monarthropalpus and probably like it, capable of piercing leaf tissues to some extent.

Cocoon. The cocoon is a product of biological activities and is therefore discussed under biology. It is ordinarily white, yellow or some shade of brown. There appear to be several types of cocoons made by gall midges. The flaxseed type by Phytophaga destructor Say consists of the dried larval skin lined by a thin, silken web. Kieffer has called attention to the compound character of the cocoon constructed by Itonida pini DeG., the external being white, resinous and easily soluble in alcohol, while the internal is silken, slight and composed of microscopic threads. Oligotrophus betulae Winn. transforms within the gall in a fine, white cocoon which may be excreted from setaceous processes, as it appears to have no filamentous structure, even under a powerful microscope. On the other hand, some of our American species of Lasioptera appear to construct spun cocoons of silk. This is very evident in the case of a species, presumably Lasioptera, inhabiting oval, spongy, subapical stem galls on Eupatorium urticaefolium. There can be no question as to the filamentous character of the structure. This is further supplemented by our observations upon the larva of Lasioptera galeopsidis Felt. This larva, prior to pupation, continues its burrow to the surface of the gall, capping the orifice with a convex silken structure. The larva was observed under a hand lens and also a compound microscope while making this cap. The head was moved back and forth across the space, carrying an irregular, pale silken thread and attaching it on either side. The delicate threads appeared to issue from the mouth and their placing was nearly as regular as is the case with some of our common lepidopterous caterpillars when constructing their more complex cocoons. These temporary covers, excluding enemies and presumably affording ventilation, appear to be made by some other species of Lasioptera. The larvae of Cincticornia pilulae Walsh, after escaping from the galls in which they winter, spin slight cocoons, probably filamentous, before transforming to the adult.

Pupa. The winter may be passed in this stage, though probably by relatively few species. Ordinarily the life of the pupa is short, it being, for example, but 3 to 5 days for Contarinia sorghicola Coq. The transformation to the pupa usually occurs within a cocoon, generally formed in the gall or in the earth. Some species have well-chitinized boring structures, such as the cephalic and thoracic horns. These are evidently used in excavating the channel to the surface in case this has not been previously done by the larva. Some forms appear to depend largely upon the cephalic horns as boring organs and others upon the thoracic structures, the two, as far as our observations go, never being strongly chitinized in the same species. The pupa ordinarily wriggles part way out before the disclosure of the adult.

Larvae. The larvae appear to secure most of their sustenance by absorption. It can hardly be otherwise in such forms as Dasyneura trifolii Loew, Contarinia canadensis Felt, Prodiplosis floricola Felt and many others which lie exposed upon the leaf, between apposed leaflets, at the bottom of various leaf folds, among the floral organs or in other deformities where there is no evidence of the plant tissues being lacerated or abraded. Even where the latter occurs, it can hardly be construed as conclusive evidence of the larva securing nourishment otherwise than by absorption. Itonid larvae boring in the stems of plants or lacerating the subcortical tissues appear to do this largely for the purpose of stimulating a flow of the nutritive plant fluids. This is particularly marked in the case of Retinodiplosis resinicola O. S., a species living in the semifluid resin exuding from wounds on pine limbs. All the Itonid galls we have examined tend to support the belief that the amount of nourishment obtained through deglutition is extremely small, since there are no signs of excreta so commonly found in galls produced by the grosser-feeding species, such as the larvae of the Tenthredinidae, Lepidoptera and Coleoptera. We must conclude that, as a rule, the digestive system, in the ordinary meaning of the term, is nearly functionless. On the other hand, certain of the predaceous larvae living as ectoparasites, for example, on aphids, on the larvae of other Itonididae or preying upon mites, lead a more active existence and probably elaborate most of their nourishment by the aid of a functional digestive system.

The development of the Itonid larva is usually rapid in leaf and blossom bud inhabiting forms, it being only about 10 days in the case of Contarinia johnsoni Sling. The duration of the larval existence in the case of Contarinia sorghicola Coq. has been given as 9 to 11 days. Conversely, in older tissues the development of the larva appears to be extremely slow, as for example, the form inhabiting the leaf folds of Carpinus and known as Cecidomyia pudibunda O. S. These larvae remain in a small, apparently immature condition for weeks.

Itonid larvae may be found living exposed upon the foliage of various plants with practically no shelter. This is true of Caryomyia glutinosa O. S. and of Cecidomyia ocellaris O. S. The former is remarkable for well-developed warts and setae, while the latter is smooth, semitransparent and nearly invisible. One larva is known to live in the rather deep reticulations on the underside of milkweed leaves, producing very little or no deformity. Larvae of certain species of Mycodiplosis subsist upon fungous-affected portions of plants and appear to depend for protection in large measure upon coloration, since they are comparatively inactive and unarmed and are frequently tinted so as to harmonize closely with their surroundings. The larvae inhabiting blossom and leaf buds, leaf folds and stem galls of various kinds are usually moderately smooth and relatively inactive. The same general observations apply to those occurring in fungi or living upon decaying vegetable matter.

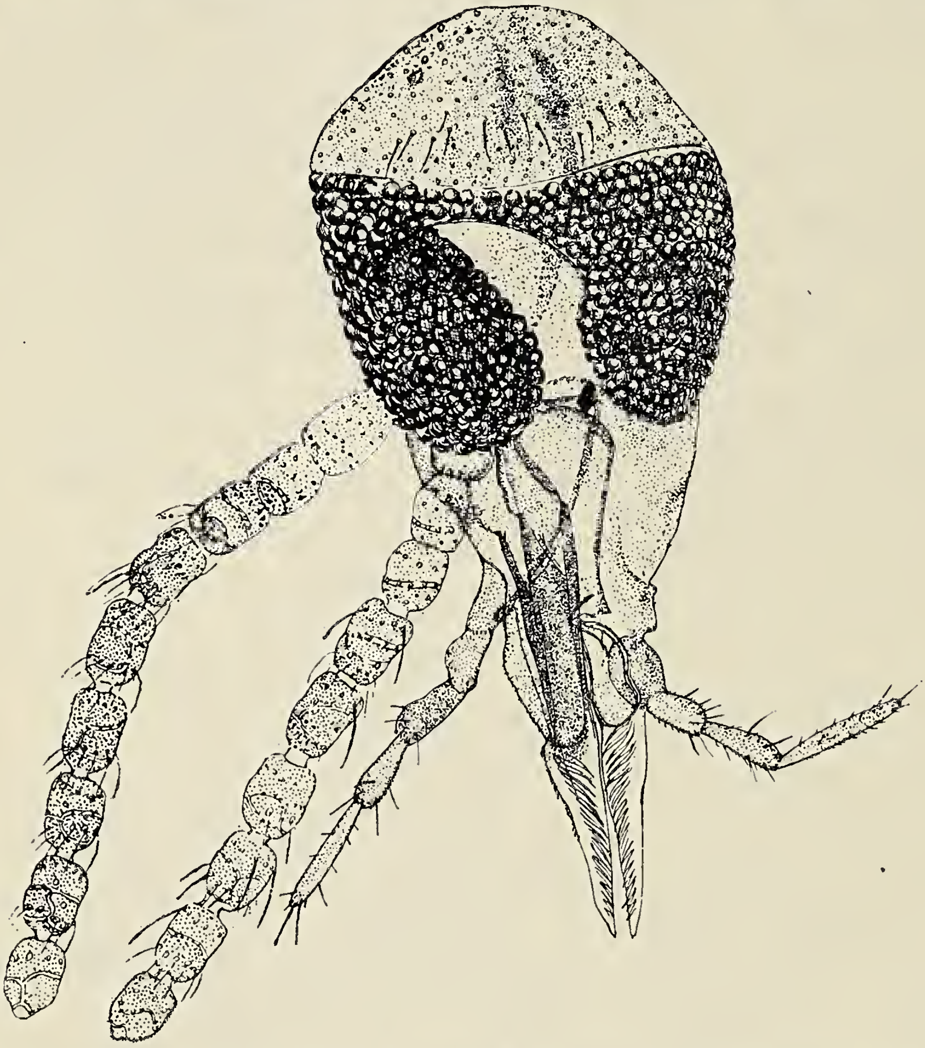

Figure 1 Clinorhyncha filicis, front view of somewhat distorted head showing eyes, antennae, palpi and the greatly produced mouth parts (Author's illustration)

An endoparasite, the European *Endaphis perfidus* Kieff., lives within the body of its host. Predaceous larvae, for example *Mycodiplosis acarivora* Felt, are highly specialized, since they move rapidly and have the anterior body segments and mouth parts well developed to meet the needs of their predaceous existence.

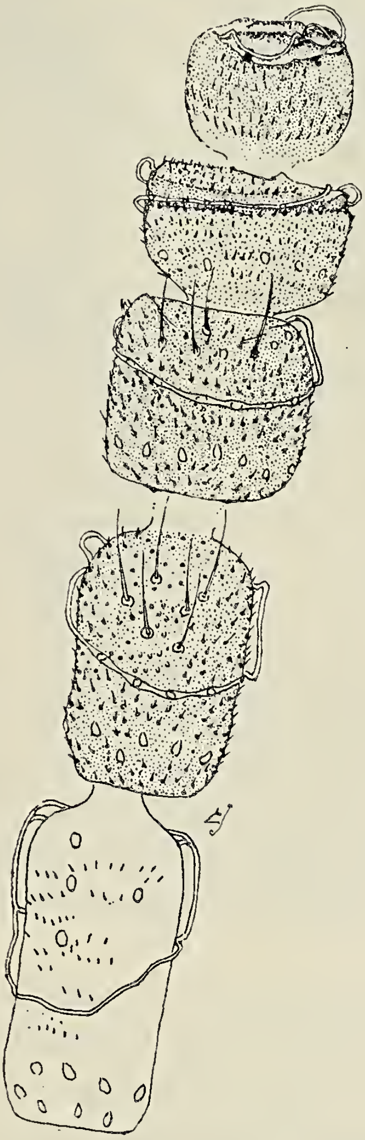

Figure 2 *Schizomyia petiolicola*, distal five antennal segments showing the great reduction of the last three (Author's illustration)

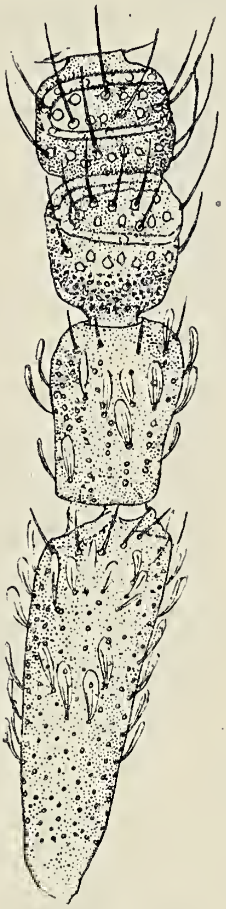

Figure 3 *Trotteria subfuscata*, basal antennal segments showing the great production of the first segment (Author's illustration)

A most characteristic movement of Itonid larvae is that produced by the maggot bringing the two extremities together and then with a sudden extension, throwing itself a considerable distance. This has been repeatedly described and may be seen in many of the larger forms, at least. Progression is also accomplished by an undulating contraction of the body, evidently with the assistance of pseudopods. This is easily observed in galleries inhabited by boring forms or in the species occurring in resin. The predaceous larvae move more rapidly, some are provided with well developed pseudopods and crawl very much as does the more highly organized caterpillar.

The breastbone appears to be of comparatively little or no value in the case of species living in blossom or leaf buds or upon leaf deformities where little or no laceration is necessary. Some investigators believe this organ may be of service in assisting the larva to reverse its position in the burrow or in its cocoon. Observations made several years ago upon Monardia lignivora Felt, show that the breastbone may be used in eroding woody tissues, since larvae were repeatedly seen in galleries containing perceptible quantities of comminuted wood fibers. We believe this structure is employed as a boring tool by many species inhabiting the stems of plants, such for example, as Neolasioptera hibisci Felt or Lasioptera galeopsidis Felt. The larvae of both of these species excavate galleries in the pith of the stems and also from the pith to the center. We are unable to find any other structure capable of doing this, while we have repeatedly seen larvae with the head and body segments retracted so that the anterior portion of the breastbone projected forward like the point of a chisel. The probable use of this structure as a boring organ is further shown by the observations of Miss Eckel on Retinodiplosis resinicola O. S. She found the soft resin full of microscropic splinters of wood fibers, particles presumably produced by the use of the breastbone.

Pedogenesis. The remarkable phenomenon of pedogenesis or the production of larvae by larvae has been well established for Miastor and several other genera in the Heteropezinae. The studies of Doctor Kahle (1908) convinced him that this is a true parthenogenesis. The ovaries in the larva mature, allow ovules to escape into the body cavity and the contained embryos, still inclosed in the membrane, develop by absorption of nourishment from the body tissues of the mother larva. This continues till the parent larva is reduced to a lifeless cuticle more or less completely filled with young. The latter escape through a rupture in the dermis and proceed to develop in the same manner. Reproduction by pedogenesis occurs throughout the warm months of the year and even into late fall and commences in early spring. The appearance of imagoes which pair and are remarkable because of the few very large eggs produced by the female, occurs in June. Doctor Kahle, after an extended series of observations, was led to believe that multiplication by pedogenesis might continue uninterruptedly, aside from the period of suspended activity in winter, for 2 or 3

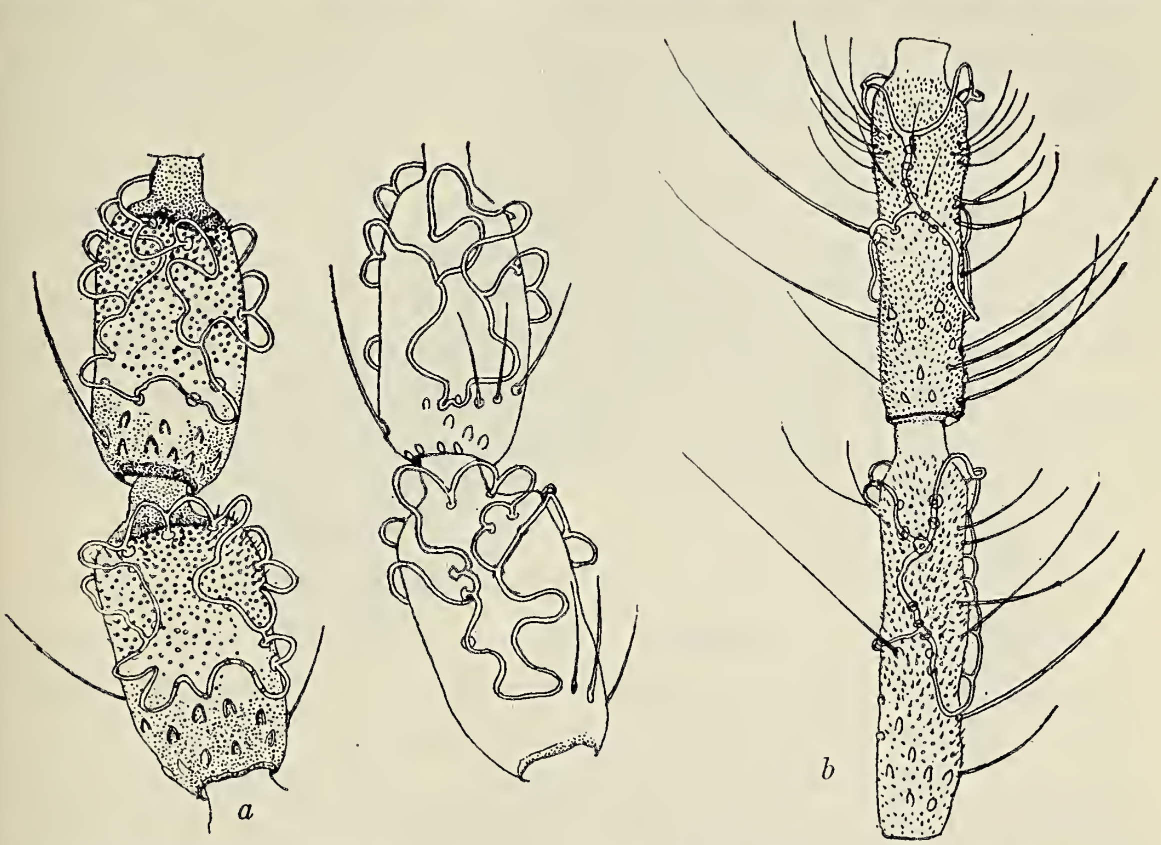

Figure 4 Schizomyia coryloides, *a*, fifth and sixth antennal segments of male, *b*, same of female, illustrating a comparatively simple type with moderately raised circumfila (Author's illustration)

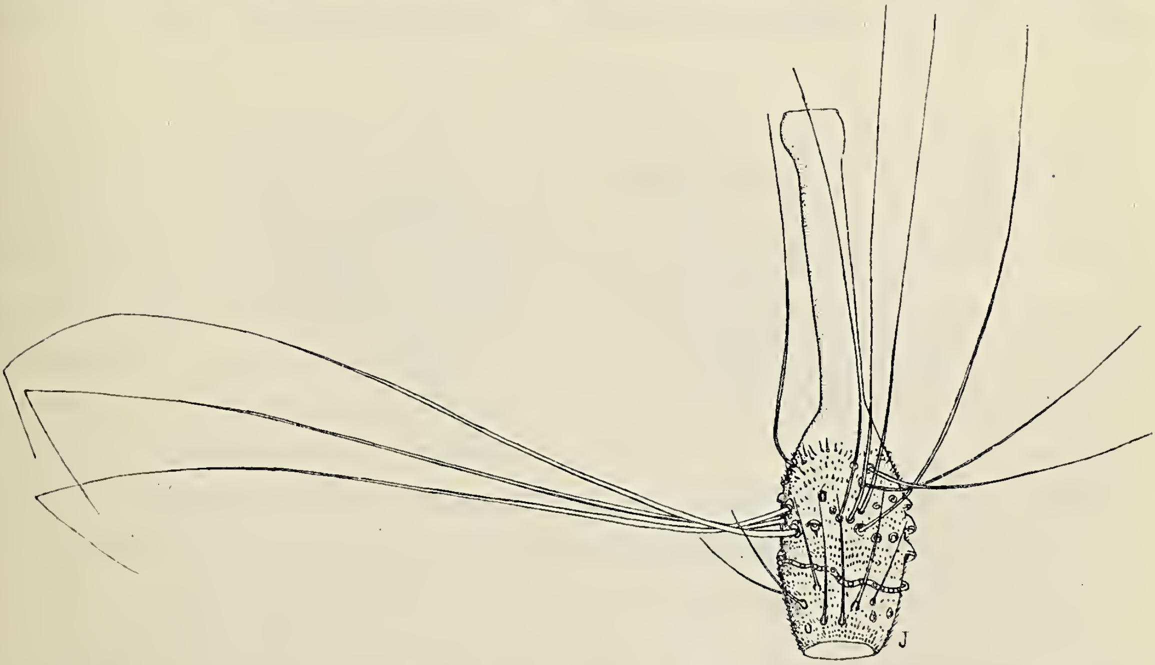

Figure 5 Holoneurus elongatus, fifth antennal segment of male showing the basal circumfilum clearly, the distal not represented and illustrating the greatly produced stem and the distal setae extending nearly parallel therewith (Author's illustration)

years. These peculiar larvae have no breastbone, in Miastor at least, until just before changing to pupae. They occur in colonies in the partially decayed bast of various trees and may be easily recognized by their frequently lying side by side in numbers and especially by the presence of mother larvae containing well-developed young. This process of reproduction is of immense advantage to species living under such conditions, since the larvae on escaping from the parent find themselves surrounded by an abundance of food and frequently so well protected by the rather firmly adhering bark as to be nearly inaccessible to various enemies. A number of generations occur during the period of hibernation for most insects, the larvae mostly becoming successively smaller before the appearance of the sexes in the spring.

STRUCTURE AND TAXONOMY

The gall midges, or Itonididae, have mostly similar habits, though they present numerous structural variations. The almost endless modifications occurring in the midges are accompanied by differences, some very sharply drawn, in food habits. This family also presents interesting cases of independent specialization along parallel lines, a response presumably to environmental factors. It is planned to not only outline the more important structural modifications, but also to explain, if possible, the more marked tendencies in specialization. This study is primarily macroscopic, if such a term can be applied to insects of almost microscopic size. It is concerned mostly with the external anatomy of the principal organs of the body.

Structure

The head and its appendages. The head is moderately large in the Itonididae; the anterior lateral angles are invariably rounded and the vertex is more or less convex. The head may be very broad in species with the mouth parts not greatly produced, while in some other forms it tapers ventrally and may be produced as a long snout or beak, this tendency reaching its highest development in Clinorhyncha H. Lw. (figure 1) and the African Farquharsonia Collin.

Eyes. The compound eyes are usually large, frequently black and occupy a considerable portion of the dorso-lateral margin of the head. They are contiguous in most species, narrowly so in the Lestreminae and most of the Heteropezinae, marked exceptions in the latter being Miastor and Oligarces with their well-separated, moderately sized, oval orbits. The narrow approximation on the median line also occurs in a number of the Porricondylariae and Lasiopterariae, Trotteria in the latter group being peculiar in the limitation of the eyes to the ventral two-thirds of the head and the absence in some species at least of facets in the narrow, median commissure. The eyes compose most of the head in some of the higher groups, such as the Asphondylariae and the Itonididinariae, being broadly approximate on the median line. The peculiar Trisopsis Kieff. presents an interesting modification in that there is a dorsal and a pair of sublateral orbits, the intervening areas being the normal chitin of the head case. An instance of incipient reduc-

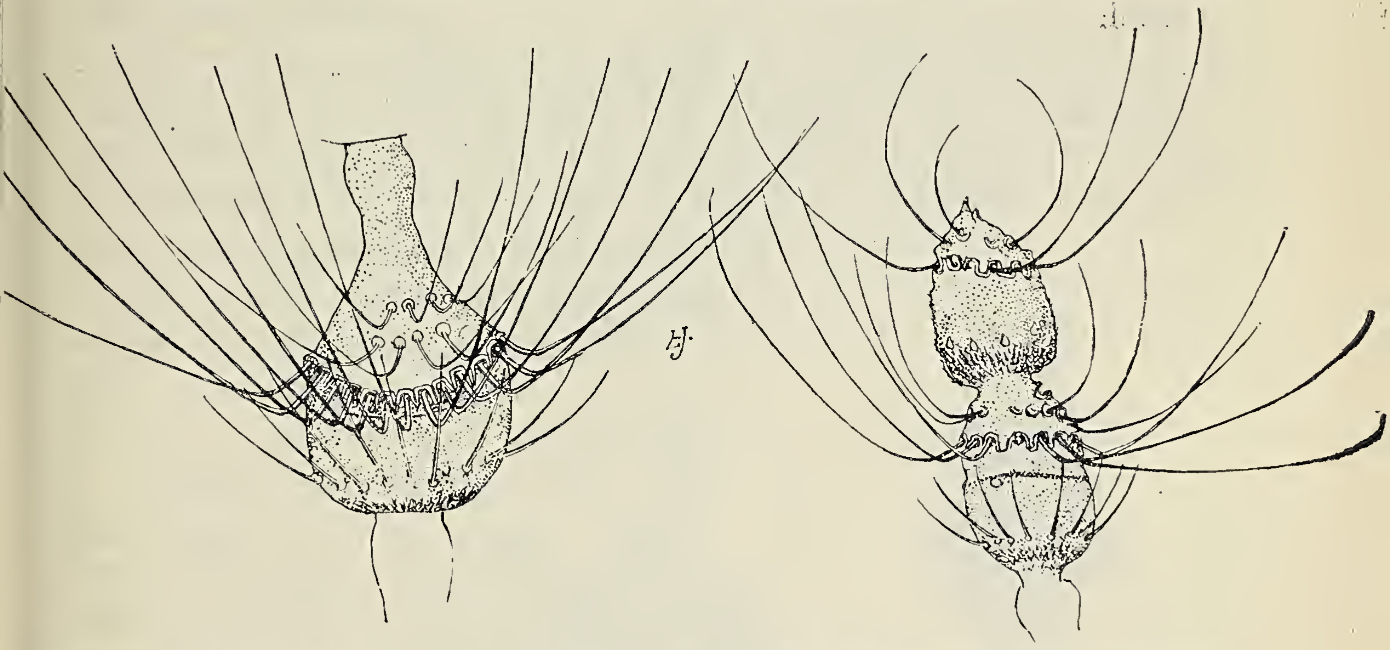

Figure 6 Campylomyza vitinea, fifth and distal two antennal segments of male, the former showing a tapering type of segment and also a typical crenulate whorl (Author's illustration)

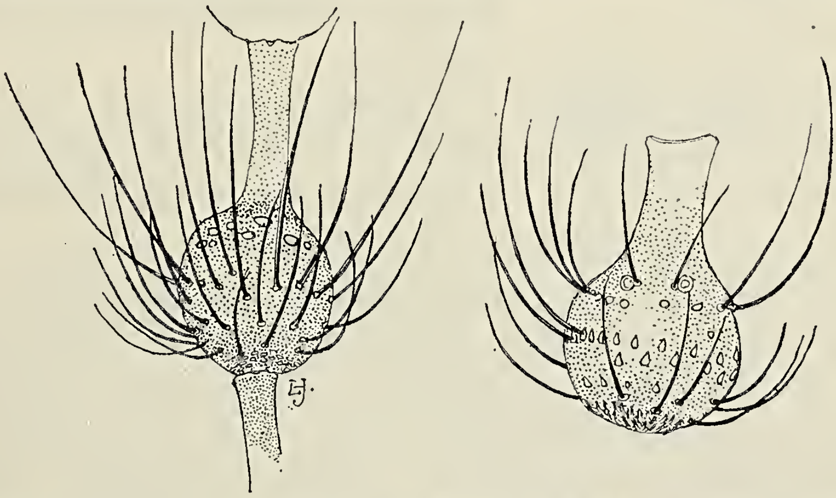

Figure 7 Joannisia photophila, fifth and tenth antennal segments of male, illustrating the globular basal enlargement bearing an irregular whorl of simple setae

tion in this direction has been noted in one species of the Lasioptera group, there being a distinct constriction at the sublateral narrow portion of the eye and a reduction in the number of facets in that area.

Ocelli. The ocelli are limited to the Lestreminae, the three arranged at the apices of a triangle, the median ocellus anterior.

Antennae. The antennae in this family present an extraordinary range in development, varying from comparatively insignificant and presumably relatively functionless organs with but six segments in the Mexican Ceratomyia Felt to very highly specialized organs with as many as thirty-nine segments in the American Lasioptera howardi Felt and forty-one in Ficiomyia perarticulata Felt from Florida.

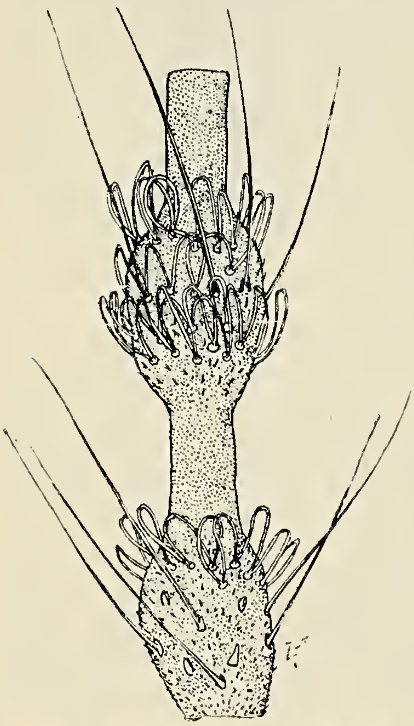

Figure 8 Dichrona gallarum, fifth antennal segment of male, showing binodose type of segment and also the peculiar doubling of moderately short circumfila (Author's illustration)

These organs are very fragile and exceedingly graceful, specially in the male Itonididinariae. They are ordinarily born in an elevated position, curving backward over the body. The insertion is between the eyes and near the middle or dorsal third of the head. The antennae bear a great variety of sensory, probably both olfactory and auditory, structures upon the flagellate segments.

Number of segments. The normal number of antennal segments among generalized flies belonging in this series is probably sixteen, that is, a greater or a smaller number means specialization by addition or reduction. The remarkable Mexican Ceratomyia Felt has only six antennal segments. The African Stephodiplosis Tav. is one of the few forms with but 12 antennal segments.

Most gall midges have fourteen antennal segments, a limitation almost invariably true of the Itonididinariae, though the somewhat anamalous Hormomyia H. Lw. with distinct Oligotrophus affinities comprises certain species with as many as twenty-five or twenty-six segments (the flagellate binodose) in the male and twenty to twenty-four at least in the female. An American species of Lasioptera Meign. has thirty-nine and of Ficiomyia Felt forty-one segments, respectively.

The Asphondylariae have almost invariably fourteen cylindric antennal segments, the distal two or three in the females of Asphondylia H. Lw. and Schizomyia Kieff. being represented by disklike rudiments (figure 2). Reduction is carried to such an extent that it results in but thirteen antennal segments in certain species of Cincticornia Felt.

The relative stability in the number of antennal segments characteristic of the Itonididinariae and the Asphondyliariae presents a marked contrast to that found among the Dasyneuriariae and the Oligotrophiariae, there being a variation in the latter two groups of from nine to twenty-five or twenty-six segments.

The Lasiopteriariae likewise show great diversity in the number of antennal segments, varying from 10 or 12 in Clinorhyncha H. Lw. to 39 in Lasioptera Meign. There may be in this group a variation between the sexes of three or four to seven in the number of antennal segments and it is not unusual to find a difference of two or possibly three among individuals of the same sex.

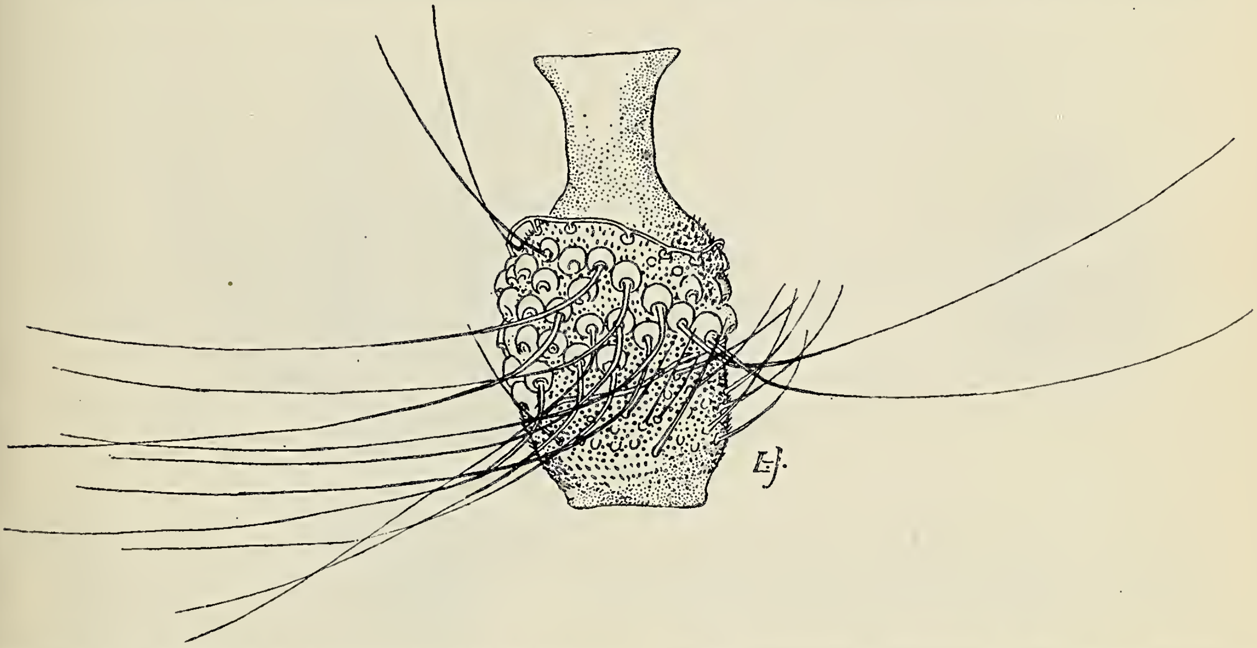

Figure 9 Rhopalomyia hirtipes, fifth antennal segment of male, illustrating a moderately long stem and the typical arrangement of setae and circumfila (Author's illustration)

There appears to be some connection between the size of the insect and the number of antennal segments. The larger forms of Rhopalomyia Rubs., Rhabdophaga Westw. and Hormomyia H. Lw. have the greatest number of antennal segments. Furthermore, marked reduction in these organs is accompanied in some instances at least, such as Tritozyga O. S. and Microcerata Felt by unusually well-developed and presumably rather highly functional palpi.

Form of antennal segments. The two basal antennal segments, constituting the scape, differ greatly from the remainder or the flagellum. The first or basal antennal segment is almost invariably obconic and while varying somewhat in its proportions, usually presents comparatively little that is characteristic, though the genus Trotteria Rübs. is easily recognized by the greatly produced basal antennal segment (figure 3) with a length 3 to 4 times greater than its diameter. Another marked exception is Endaphis Kieff., which has the dorsal margin prolonged toothlike to the middle of the second segment.

The second antennal segment is usually globose or sub-globose and sometimes deeply excavated distally to form a some-what bowl-shaped structure. The European Acodiplosis Kieff. is peculiar on account of the ventral spine or tooth apically.

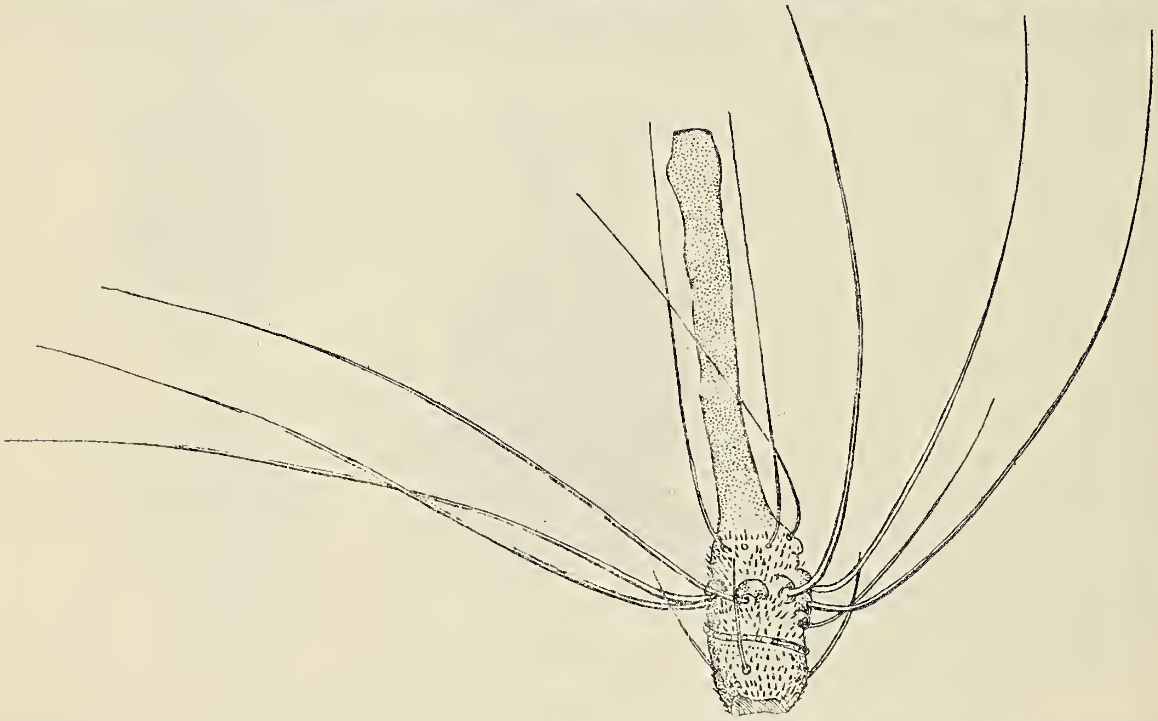

Figure 10 Colpodia diervillae, fifth antennal segment of male, showing the greatly produced stem and a typical arrangement of setae and circumfila (Author's illustration)

The flagellate antennal segments vary in number from four to thirty-nine, the simplest type is a plain cylinder and a study of antennae in various groups shows that there may be a great variety of modifications. A simple type of antennal segment is seen in Schizomyia Kieff. (figure 4) and less evidently in Lasioptera Meign. The common cylindric form may be modified by a constriction at the distal portion which practically results in a comparatively simple type of segment having a basal enlargement and a constricted, smooth, slender portion distally, frequently termed the stem. The modification may be comparatively slight and result in a hardly apparent stem or extreme development, in which latter case the stem may have a length three times the basal enlargement, a condition seen in Rhabdophaga porrecta Felt, and also in certain Porricondylariae (figure 5). A modification of the cylindric form is found in the conic or top-shaped segment of Campylomyza and in this case the constriction in diameter appears to progress gradually from the base to the tip. Joannisia Kieff. (figure 7) is somewhat peculiar with its globular basal enlargement and cylindrical stem as long or longer than the swelling.

The Itonididinariae present a more striking modification in that in addition to the distal constriction or stem there is also one near the basal third and a consequent dumb-bell-shaped structure with

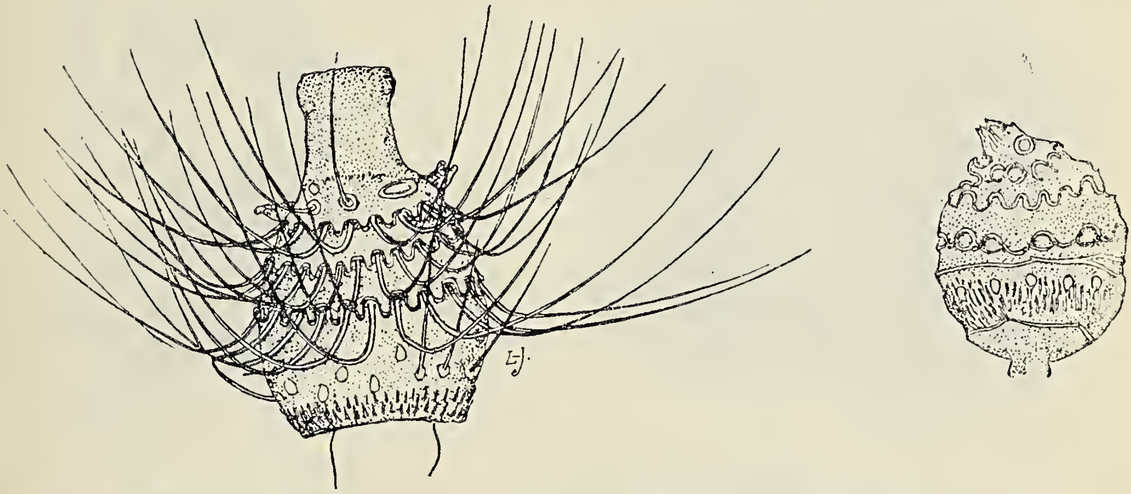

Figure 11 Prionellus graminea, fifth and terminal antennal segments, the former illustrating a well-developed series of crenulate whorls (Author's illustration)

a free stem at one extremity (figure 8). A closer examination of this group shows a considerable series with equal or nearly equal enlargements on the flagellate antennal segments and another series with plainly unequal enlargements, each exhibiting other modifications which will be discussed later. The distal enlargement is almost invariably the larger in the series with unequal enlargements, though the peculiar Xenodiplosis Felt is remarkable because this relationship between the two enlargements is reversed, the larger one being basal instead of distal.

There are marked sexual modifications in the forms of the flagellate antennal segments in certain groups, specially in the Dasyneuriariae, the Oligotrophiariae and the Itonididinariae. Females of the former two almost invariably have the distal stem shorter than in the opposite sex, while in those of the last named, the segments are almost invariably cylindric and with a more or less well developed stem, a most marked contrast to the binodose male Itonididinariae.

The constricted portion of the flagellate antennal segment, be it distal or otherwise, is almost invariably smooth, though occasionally it may be somewhat fluted or slightly corrugated. The tip of the distal antennal segment, rudimentary or otherwise, is usually clothed in somewhat the same manner as the other portion of the segment.

The first and second flagellate segments, the third and fourth of the antennae as a whole, are very frequently fused. This is specially true in the higher tribes and is most evident in certain Lasiopterariae, where the third and fourth segments are so closely united as to form practically one compound segment.

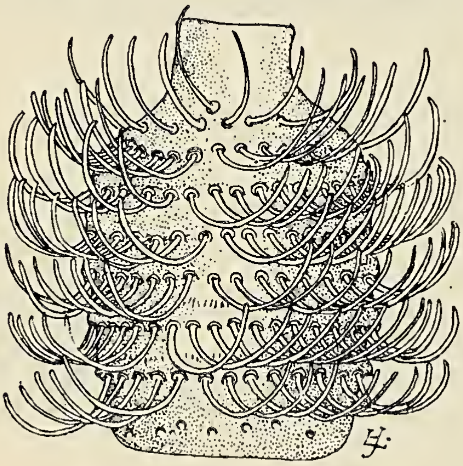

Figure 12 Corinthomyia cincinna, fourth antennal segment of male, illustrating a peculiar type very suggestive of, although different from, crenulate whorls (Author's illustration)

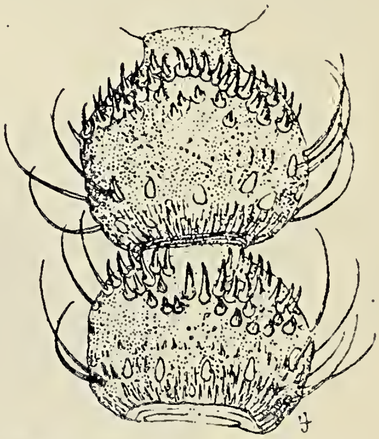

Figure 13 Cordylomyia brevicornis, fourth and fifth antennal segments of male, showing the peculiar, irregular, subapical whorl of short stout spines (Author's illustration)

Sensory and other structures. The variations mentioned in both number and form of the antennal segments are neither greater nor more significant than are the differences in sensory and other structures.

Rudimentary setae or chitinous points. Rudimentary setae or chitinous points almost invariably occur upon the enlarged portion of the segment throughout the entire group, being particularly heavy and well developed in the Lasiopterariae. They are wanting or nearly so in certain of the Campylomyzariae.

Setae. The ordinary setae or hairs taper slightly and are usually arranged on the flagellate segments with a considerable degree of regularity. Certain forms, such as Joannisia (figure 7), have only a more or less well-defined basal whorl of setae with smaller hairs irregularly distributed over the surface of the segment. Most gall midges have a well-developed, rather thick subbasal whorl of relatively short, slightly curved, stout setae, and in many groups a thick subapical band of longer, strongly curved setae, the latter frequently arising from conspicuous tubercles and generally much thicker and more produced upon the ventral face (figure 9). This arrangement is typical of the Dasyneuriariae, the Oligotrophiariae and to a less extent of the Itonididinariae. The subbasal whorls are but slightly developed in the Lasiopterariae and less so in the Asphondylariae. The latter have the segments uniformly clothed with very short setae or scales, and little indication of whorls of longer setae. In addition to the above there may be, especially in the Porricondylariae, a sparse apical whorl of setae on the basal enlargement, the hairs usually extending nearly parallel with the axis of the segment (figure 10). The minutely denticulate hairs of the Seychelle midge, Chrysodiplosis Kieff., deserve mention.

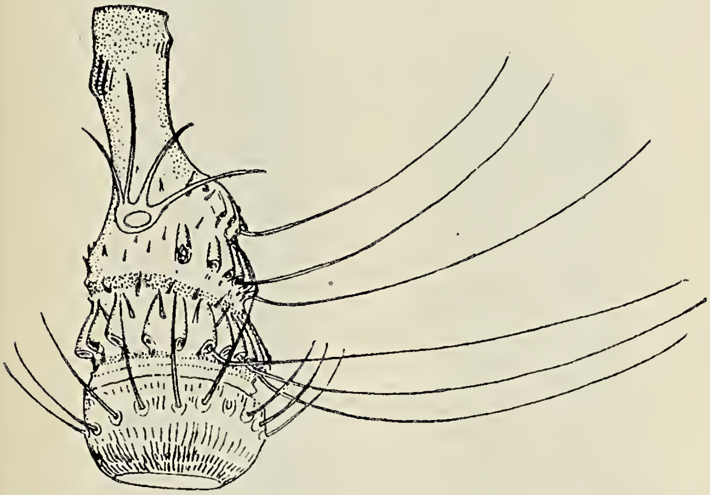

Figure 14 Lestremia pini, fifth antenal segment of male, illustrating the peculiar, subapical digitate process (Author's illustration)

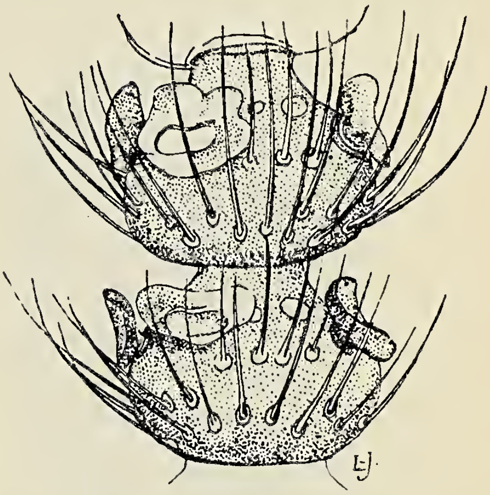

Figure 15 Monardia lignivora, fifth and sixth antennal segments of female, illustrating the whorls of stemmed disks (Author's illustration)

Crenulate whorls. This term is restricted to certain peculiar whorls of long, stout setae arising from a chitinous, crenulate base (figure 11) and limited to the Campylomyzariae, though Johnsonomyia Felt presents an approximation to this condition. The crenulate whorls are probably but specialized whorls of setae. A peculiar and striking modification, presumably of these structures, is seen in Corinthomyia Felt, (figure 12).

Subapical spines and related appendages. The peculiar spines discussed here appear to be limited largely to the Campylomyzariae and the Heteropezinae. The subapical whorls of short, stout, occasionally recurved tapering spines (figure 13) are characteristic of the genus Cordylomyia Felt and may be simply modified forms of the crenulate whorls mentioned above, though it is possible that they are a primitive type of an olfactory organ.

A markedly different development is seen in the peculiar digitate appendages set in subapical whorls of four or so and found in certain genera. They arise from large, oval, dermal orifices, may have two, three or possibly more branches, and are undoubtedly special sense organs (figure 14). A further modification, probably exhibiting a higher degree of specialization of the same general type of sensory organ, is seen in the whorls of " stemmed disks " (figure 15) peculiar to the genus Monardia. These are probably olfactory in function. A similar structure occurs in Miastor americana Felt.

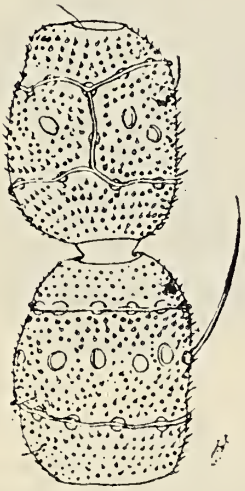

Figure 16 Asteromyia vesiculosa, fifth and sixth antennal segments of male, illustrating typical low circumfila (Author's illustration)

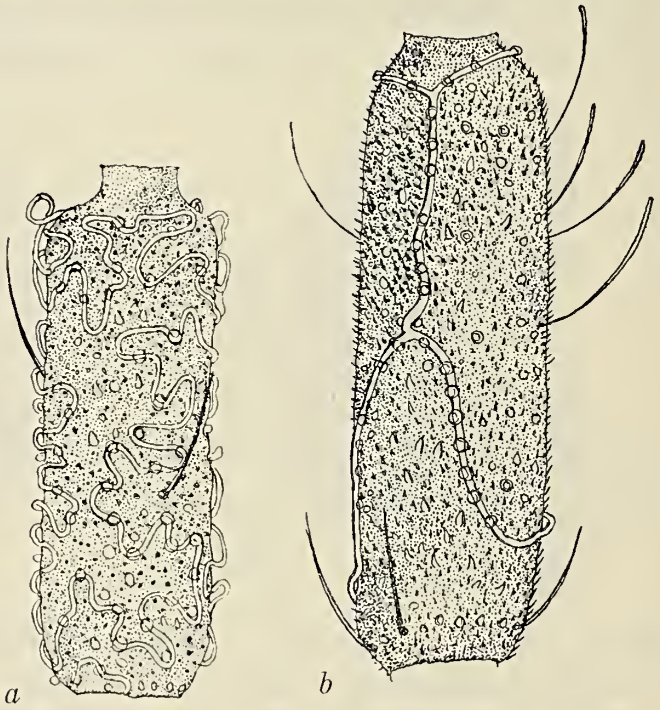

Figure 17 Asphondylia monacha, sixth antennal segment, *a*, male; *b*, female, illustrating the cylindrical type of segment and also the marked differences in the development of the circumfila between the sexes (Author's illustration)

Circumfila. These peculiar structures appear to be limited to the Itonididinae. They are presumably auditory in nature and are discussed by Europeans under the names of arched filaments (verticili arcuati, and filets arques) and bow whorls (bogenwirtel) because they were first detected in the highly specialized form in the male Itonididinariae.

A generalized type of circumfila (figure 16) occurs in the Lasiopterariae. They are merely slightly elevated threads supported by slender stalks and girdling the flagellate segments sub-basally and subapically and united on at least one face of the segment. These structures are similar in both sexes. Rhabdophaga and its allies present a modification in the male with the somewhat more arched circumfila. Practically the same is true of Rhopalomyia Rübs. The female Asphondylia H. Lw. with the greatly prolonged, cylindric antennal segment has similar circumfila, though the threads uniting (figure 17*b*) the two bands must necessarily be greatly prolonged. A most striking variation on some accounts is found in the male (figure 17*a*). The circumfila in this sex consist of a more or less variable series of extremely tortuous, slightly elevated threads reaching from the apex of the segment to its base, usually in the

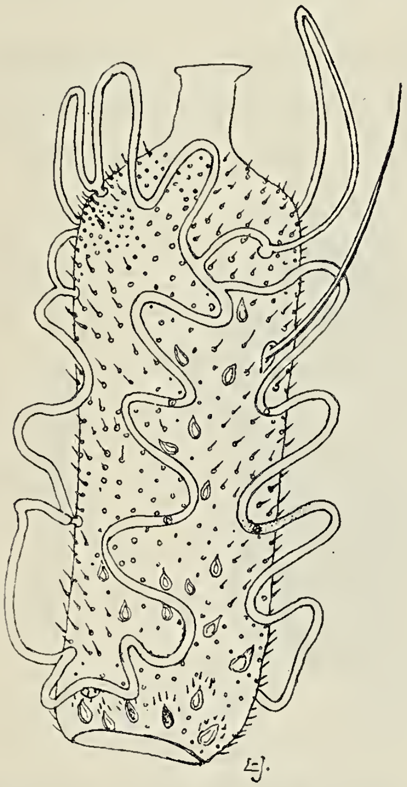

Figure 18 Schizomyia macrofila, sixth antennal segment of male, illustrating the thickened and somewhat elevated circumfila (Author's illustration)

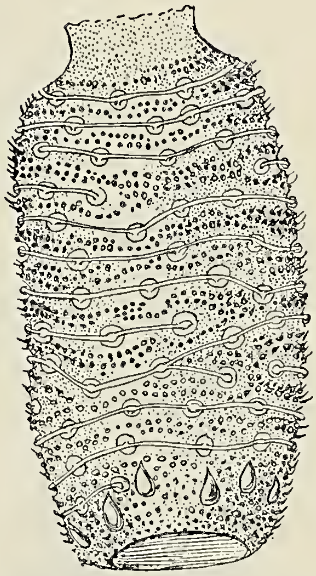

Figure 19 Cincticornia transversa, sixth antennal segment of male, illustrating a highly developed series of low, transverse circumfila (Author's illustration)

form of two more or less well-defined loops. The genus Schizomyia Kieff. presents a greater degree of specialization in that the circumfila are thicker, more elevated and more strongly convolute (figure 18). The genus Cincticornia Felt is noteworthy in that the male antennal segments may be girdled by ten or more low, anastomosing circumfila (figure 19) while the antennal segment of certain females is literally inclosed in a coarse reticulation of these peculiar structures (figure 20). A very similar condition is seen in the Australian Eocincticornia Felt.

The females of certain species of Cincticornia Felt present a condition (figure 21) intermediate between that just described and the form characteristic of the female Asphondylia. Most of the females of the Itonididinariae exhibit somewhat the same generalized type of circumfila found in the less specialized tribes, although certain forms have these peculiar organs developed to nearly as great an extent as in the males. The great majority of the males in the Itonididinariae are easily recognized by the greatly produced circumfila, the loops being prolonged to form relatively enormous bowlike structures (figure 22) although the more generalized males exhibit an intermediate condition as far as the development of the circumfila are concerned.

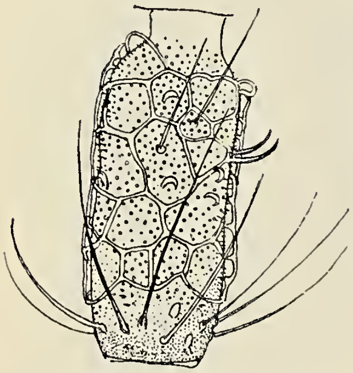

Figure 20 Cincticornia sobrina, fifth antennal segment of male, illustrating a reticulate development of the circumfila in this genus. (Author's illustration)

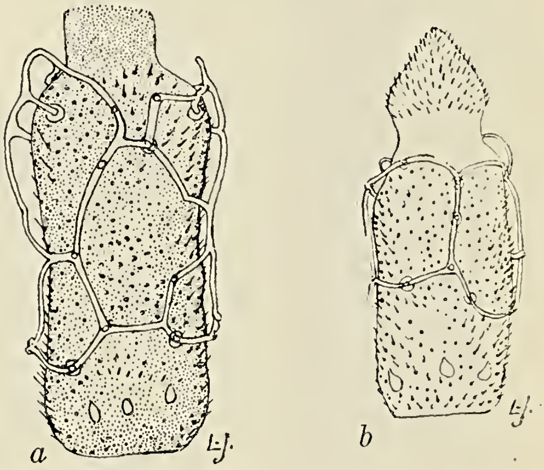

Figure 21 Cincticornia simpla, fifth *a*, and distal, *b*, antennal segments of female showing a comparatively simple type of circumfila (Author's illustration)

The Itonididinariae are easily divided into two groups by the number of circumfila in the male. The genus Contarinia Rond.

(figure 23), for example, is more easily recognized by the occurrence of but two even circumfila in the male than by the apparent uniformity of the enlargements on the antennal segments. The genera Bremia Rond, Aphidoletes Kieff. and segregates therefrom (figures 24, 25) are remarkable because the slender circumfila as well as the setae are greatly produced on the dorsal side of the segments, even to a length equal to twice that of the entire segment. Furthermore, Bremia is unusually interesting because the middle circumfilum remains in the primitive condition seen in most females, and nearly the same modification is found in the basal circumfilum of Mycodiplosis holotricha Felt though such a condition is unknown elsewhere in the genus. There is rarely a connection between the two or three circumfila on a segment in the male, although an evi-

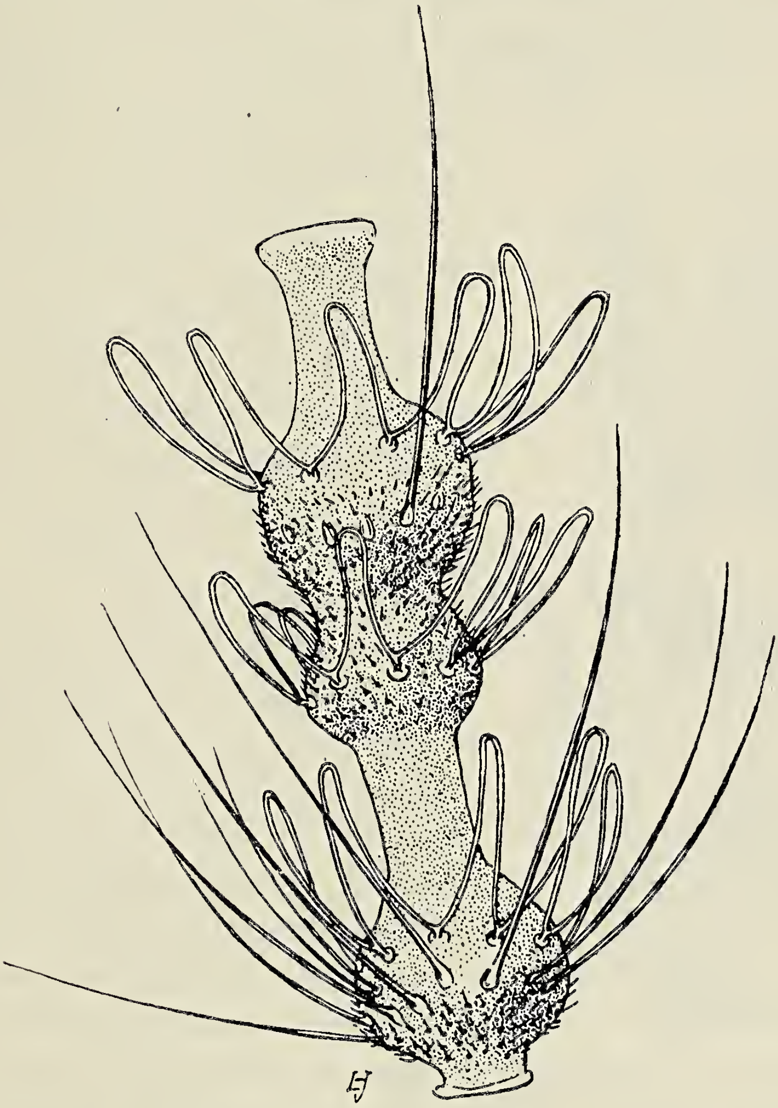

Figure 22 Karschomyia viburni, fifth antennal segment of male, illustrating a trinodose segment and the greatly developed circumfila in one of the trifila group (Author's illustration)

dently abnormal connection of this character has been observed in the case of Hormomyia americana Felt (figure 26).

The Porricondylariae, although considered more generalized than other Itonididinae, exhibit remarkable variations in the circumfila. There is a marked tendency toward the production of relatively conspicuous loops and of long, slender tips at the apex of the segment. A most unique type occurs in the genus Winnertzia Kieff. (figure 27) in which the circumfila appear to be modified to form horseshoelike appendages, one on each face of the segment, the produced free ends extending beyond the apex of the enlarged portion of the segment, while the supporting vertical threads arising from the segment give the appearance of nails.

These structures seem to have no homologons in related groups. They can hardly be considered as modified setae, since they are uniform in diameter and composed of solid homogeneous chitin. It has been suggested that these organs might be the remnants of hypodermal lamellae, a theory which can hardly be sustained, since nowhere have we traces of any such modification. It is possible the circumfila may be hypodermal structures which, through a process of development, have migrated from the interior of the antennal segment, becoming external and thus of greatly increased value as auditory organs.

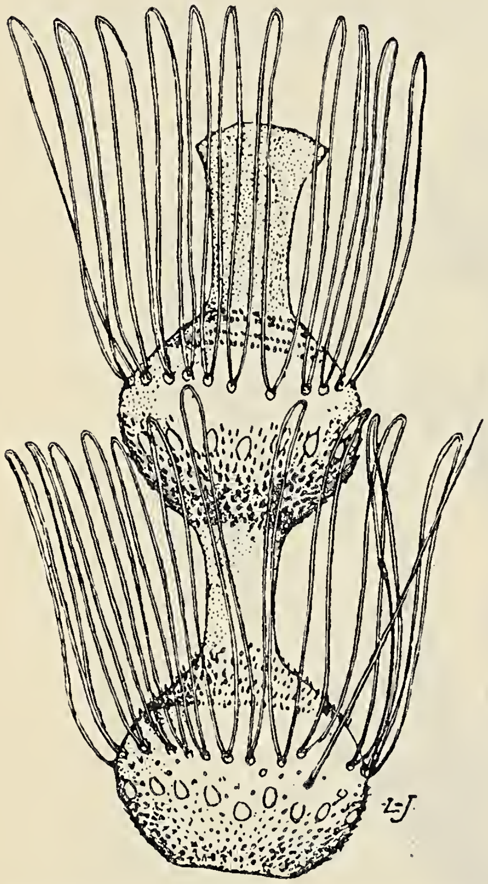

Figure 23 Contarinia pyrivora, fifth antennal segment of male, illustrating greatly developed and peculiar circumfila in the bifila (Author's illustration)

Palpi. The normal number of palpal segments appears to be four (figure 28) although these organs may become greatly reduced (figure 29) in any one of the tribes and in one genus, Oligarces Mein., appear to be wanting. In certain species these organs are attached to a rudimentary subsegment, appearing to be quinquearticulate. The palpi are usually sparsely setose and frequently rather thickly ornamented with minute setae arranged in irregular, transverse series or they may be more or less thickly covered with scales as in the Lasiopterariae and in Brachyneura Rond. of the Heteropezinae.

There is a rather conspicuous sensory pit, probably olfactory in nature, on the basal segment of certain species of Campylomyzariae.

The thorax and its appendages. The prothorax is rudimentary in most species of this group, although in Clinorhyncha H. Lw. and Asynapta H. Lw. it is prolonged.

The mesonotum is well developed and in the genus Hormomyia remarkable because of its being greatly produced over the head. The dorsum of the mesonotum has a pair of submedian lines converging posteriorly, frequently thickly haired, usually of a different color from the remainder of the dorsal surface and generally concolorous with the posterior median area. The dorsal surface of the mesonotum may be smooth and shining, dull or variously colored, while the lateral and anterior margins in some species may be widely bordered by setae or narrow scales.

The metathorax is normal. The scutellum is well developed, usually prominent. It may be sparsely scaled or setose apically and varied in color. The postscutellum is generally smooth, shining and frequently differs in color from the scutellum.

Wings. These most important organs are of great value in taxonomic work. They present in certain groups most satisfactory characters for the delimitation of subfamilies and tribes.

The costal vein is a thickening of the anterior margin of the wing which may extend with scarcely perceptible tapering to the posterior margin or may be interrupted at its union with the third vein. It is frequently the stoutest vein, usually rather thickly haired and in the Lasiopterariae, (plate 2, figures 4, 7, 8), Asphondylariae (plate 3, figures 2, 3) and some other forms may be thickly scaled.

Subcosta is a relatively inconspicuous vein uniting with costa usually before the basal half and in some forms at the basal fourth. It is frequently rather thickly scaled as in costa and may be united by a distinct crossvein to the third vein. It is probable that in many forms subcosta has fused basally with the first branch of radius.

The third vein, as we have termed it, really the major portion of radius, is an extremely important vein from a taxonomic standpoint. It probably comprises at least the second and third branches of radius. The third vein in the more generalized groups, such as the Lestremiinae and the Porricondylariae of the Itonididinariae, is united by a distinct crossvein to subcosta (plate 1, figures 1–9). Frequently it appears to arise from equal branches (plate 1, figure 9) uniting with subcosta and the base of the fourth vein. The third vein usually joins the margin of the wing near its apex, sometimes well behind the apex and in such highly specialized forms as Lasioptera and its allies, it may unite with costa at the basal half or even at the basal third (plate 2, figures 4, 7–8). This vein, in the Lasiopterariae, is thickly scaled or haired, like costa and subcosta. Camptoneuromyia Felt (plate 2, figure 10) and Trotteria Kieff. of this tribe are remarkable because the third vein describes a broad arc before uniting with the anterior margin of the wing.

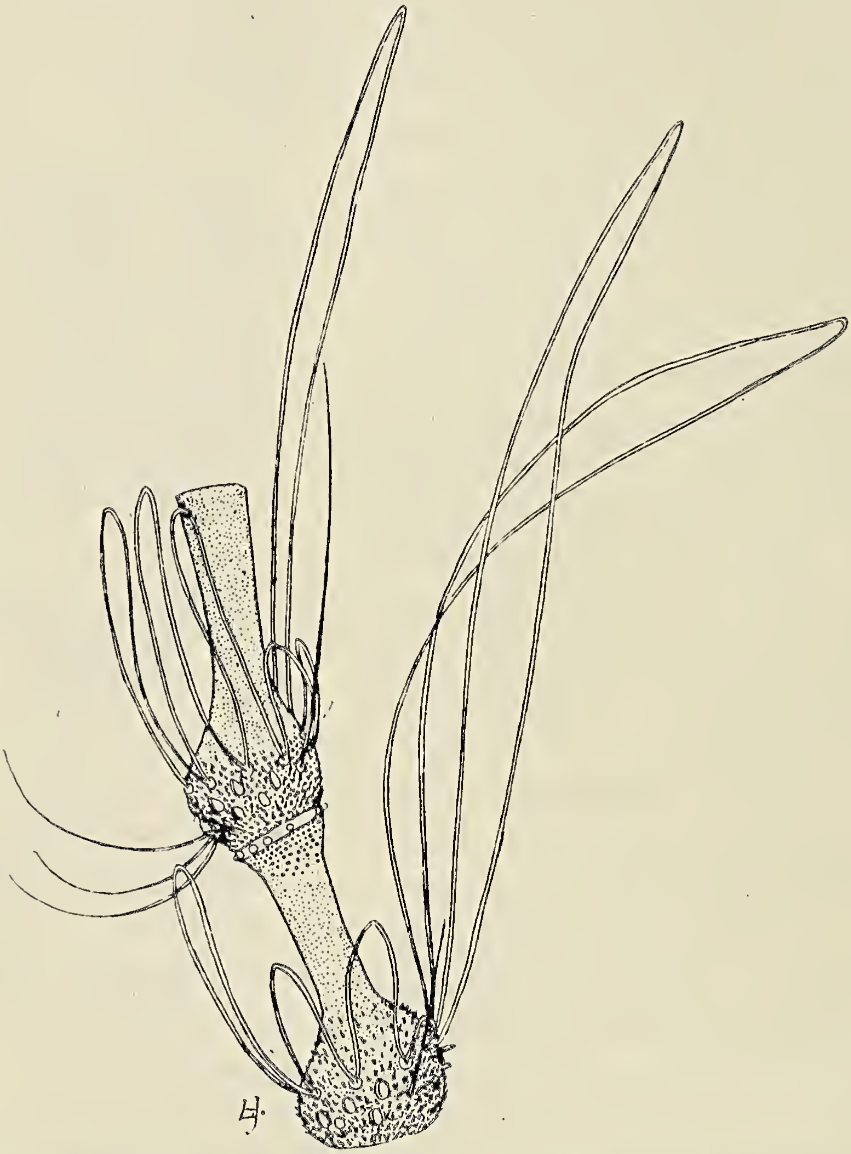

Figure 24 Bremia filicis, fifth antennal segment of male; note the greatly produced loops on the dorsal aspect of each node and also the rudimentary circumfilum at the base of the distal node (Author's illustration)

The distinct crossvein mentioned in the preceding paragraph is an important taxonomic character, since it occurs throughout the Lestremiinae and also in the Porricondylariae. There are apparently rudiments of this vein in other groups, but the chitinization is so evanescent as to give no trouble as a rule in distinguishing between a well-defined vein and its absence, aside possibly from Lopezia Tav. and Obolodiplosis Felt. The position of the crossvein is sometimes of generic value. Winnertzia Kieff. (plate 1, figure 8) is easily recognized by its crossvein and to a certain extent the same is true of Colpodia Winn. (plate 1, figure 4).

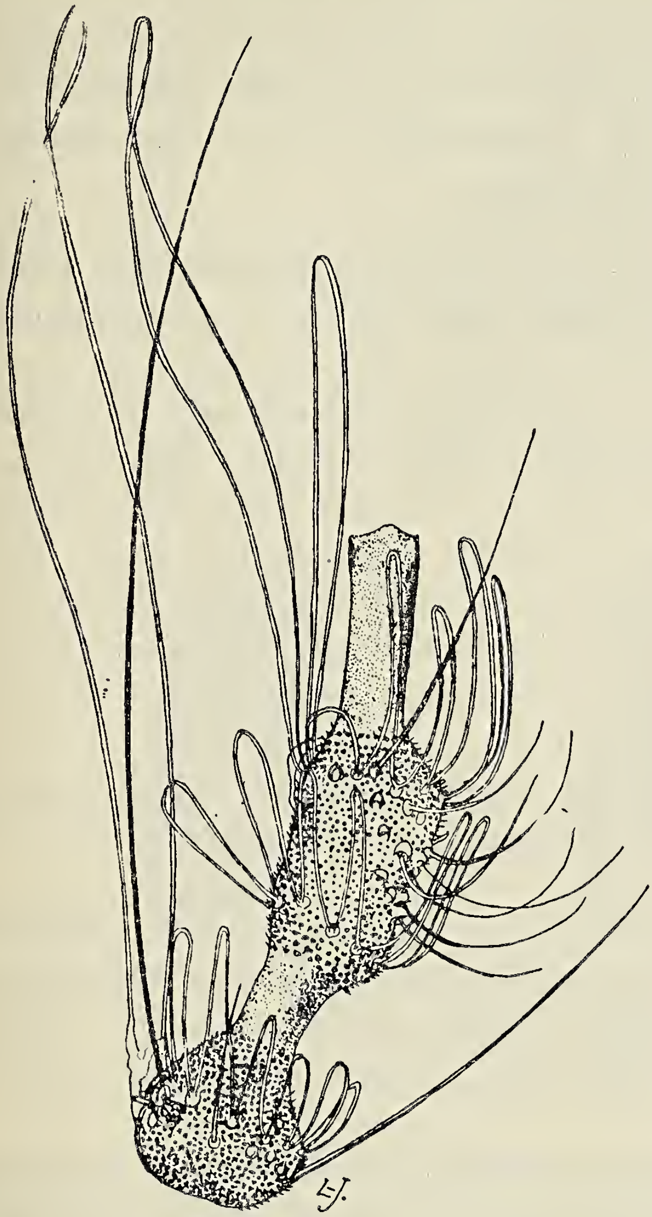

Figure 25 Aphidoletes hamamelidis, fifth antennal segment of male; note the greatly produced loops on the dorsal aspect of the nodes and also the well-developed, although smaller, basal circumfilum on the distal enlargement (Author's illustration)

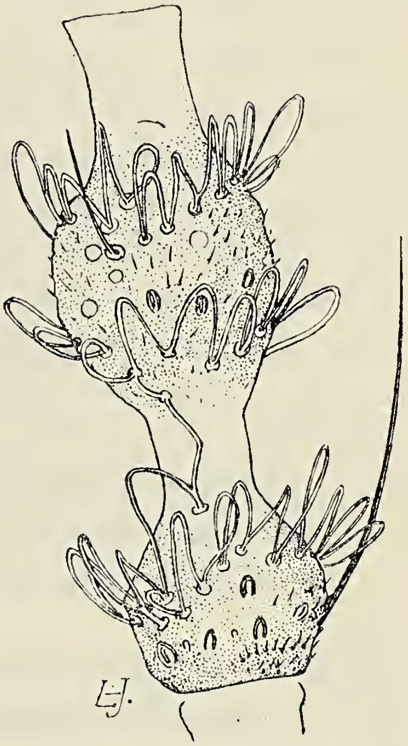

Figure 26 Hormomyia americana, twelfth antennal segment of male, showing relatively short circumfila in the Itonididinariae and also an unusual connecting filum extending from the basal to the middle circumfilum (Author's illustration)

The fourth vein, morphologically the fourth and fifth branches of radius, is rudimentary and forked in the tribe Lestremiinariae (plate

1, figures 1, 2), it being reduced to a simple rudiment in the Campylomyzariae (plate 1, figure 3).

The fifth vein is usually relatively straight and joins the posterior margin near the distal third or fourth (plate 1, figure 2).

The sixth vein may be simple (plate 1, figure 2) as in a number of generalized forms, or it may fuse basally with the fifth (plate 1, figure 3), producing the fork characteristic of the Itonididinae and present in many Campylomyzariae.

The wing veins may be greatly reduced and almost absent. This is especially true in the anomalous Heteropezinae, several forms at least having rather narrow wings with practically no veins (figure 30).

The membrane is usually rather thickly clothed with fine hairs. Brachyneura Rond. and Lasiopteryx Westw. (plate 2, figures 1, 2), are remarkable because the membrane is thickly clothed with scales or broad hairs. Some genera, especially Lestodiplosis Kieff. have the membrane and setae thereupon variously marked with fuscous. The South American Bruggmanniella Tav. is unique in possessing a brown, opaque subcostal cell, a development which appears to some extent elsewhere in the group.

Several apterous Itonididae have been described. Kieffer states that in apterous females the scutellum is never so prominent as in the case of winged males.

Halteres. The halteres or balancers are long, slender, spatulate organs possibly attaining their maximum development in Hormomyia H. Lw. and presenting considerable variation in development. They may be sparsely clothed with hairs or scales and are variously colored.

Legs. The legs in this group are usually fragile, slender, attaining their maximum development possibly in certain of the Itonididiinae. They are shorter and relatively stouter in the Lestremiinae and Heteropezinae. They are usually covered with scales or irregular, applied hairs.

Coxae. The coxae are not prolonged and are at most two or three times longer than thick.

The femora are rather long, slender, slightly tapering at either extremity.

The tibiae are almost invariably unarmed, that is without apical spines. The only exception is found in Trotteria Rubs., a genus undoubtedly belonging in this group though somewhat anomalous in the possession of small spines at the apex of the tibiae.

Tarsi. The normal number of segments is five. The Lestremiinae have the first or metatarsus longer than the following segments, while in the Itonididinae the first segment is greatly reduced, being almost rudimentary and more firmly attached to the legs than the following segments. The Heteropezinae are remarkable on account of the reduction in the number of the tarsal segments, certain genera having four, others three, while the minimum number is seen in Oligarces with its biarticulate tarsi. The second, third, fourth and fifth segments are usually successively shorter, the last bearing claws.

The claws may be simple (figure 31), dentate (figure 32) or pectinate (figure 33). They vary greatly in development, the very heavy, strongly curved, simple claw being a characteristic of Asphondylia and its immediate allies.

The pulvilli arise at the base of the claws. They may be rudimentary or well developed, frequently attaining a length one-half that of the claws, sometimes as long as the claws and occasionally distinctly longer. We have applied this term to the middle lobe, although some European authors have employed the term empodium, restricting pulvilli to the lateral, usually smaller lobes on each side of the central organ.

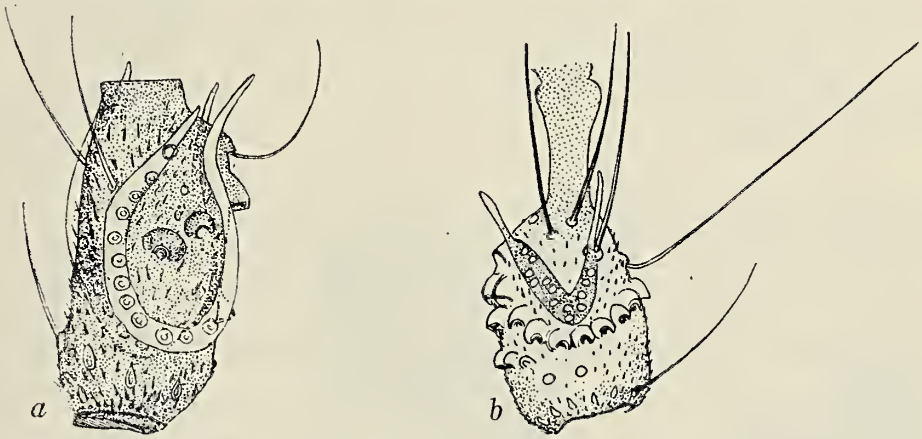

Figure 27 Winnertzia calciequina, *a*, sixth antennal segment of female, showing "horseshoe" circumfila, *b*, ninth antennal segment of male showing a modification of this structure (Author's illustration)

The abdomen and its appendages. The abdomen is moderately long and varies from fairly stout to slender. It may be nearly naked, sparsely clothed with fine or coarse setae, or thickly covered with scales, and may vary in color from pale yellowish transparent to orange yellow, reddish brown, dark brown marked with white, or almost black. It normally consists of nine nearly homogeneous segments, the terminal ones bearing the genitalia in the male and modified to form the basal portion of the ovipositor in the female.

Genitalia. These organs normally project dorsally and may be briefly described as a large pair of pincers with the more important organs protected by chitinous plates.

Basal clasp segment. This is the larger, stouter basal portion of the pincers, a structure which is frequently thickly clothed with stout setae. This segment is usually stout, occasionally very stout, and invariably forms the major portion of the genitalia. It may be simple or bear setose lobes basally as in Lestodiplosis Kieff. and in certain genera, notably Schizomyia Kieff. and Lobodiplosis Felt (plate 7, figure 2), there may be an apical lobe ventrally extending beyond the attachment of the terminal clasp segment, making the latter distinctly subapical. Certain genera, such as Metadiplosis Felt and Epidiplosis Felt are noteworthy because of the chitinous or setose apical processes.

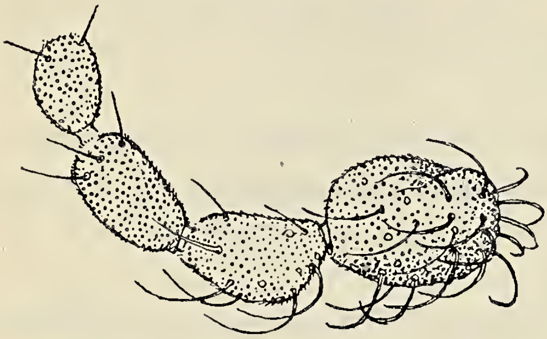

Figure 28 Joannisia photophila, palpus showing four well-developed although short segments (Author's illustration)

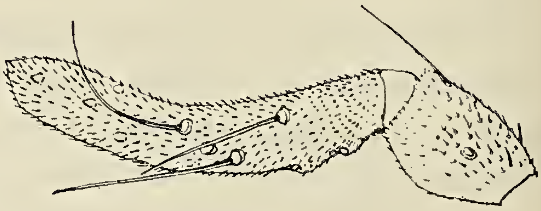

Figure 29 Rhopalomyia capitata, biarticulate palpus of male (Author's illustration)

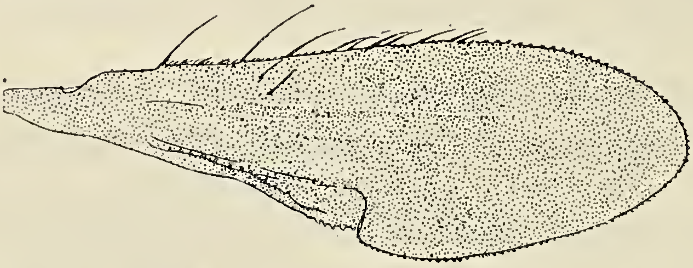

Figure 30 Leptosyna quercivora, wing showing almost complete absence of veins (Author's illustration)

Terminal clasp segment. It is invariably more slender than the basal clasp segment and usually shorter, although in a few remarkable forms, it is distinctly longer (plate 8, figures 1, 2). This segment when short and stout, and especially when greatly swollen, may be rather thickly clothed with short, stout setae, a condition never obtaining when it is greatly produced. The apex is almost invariably armed with a chitinous tooth which may be single as in Rhopalomyia Rübs. (plate 6, figure 2), nearly equally bidentate as in Asphondylia H. Lw., serrate as in Cincticornia Felt (figure 34), or deeply and narrowly incised as in many of the Itonididinariae. The general form and structure of this organ is of great value in establishing the systematic position of the species.

Dorsal plate. The dorsal plate belongs with the ninth abdominal segment and may be left attached thereto in dissecting the genitalia. It is usually short, relatively rather stout, sometimes truncate, frequently bilobed and usually rather thickly setose.

Ventral plate. This structure lies just below the dorsal plate and appears to belong to the tenth abdominal segment. It is usually thinner than the dorsal plate, frequently longer and occasionally greatly produced. The distal margin may be narrowly or broadly rounded, truncate, broadly or narrowly emarginate and sometimes deeply so. The lateral angles are frequently sparsely setose. This organ is often of great service in taxonomic work.

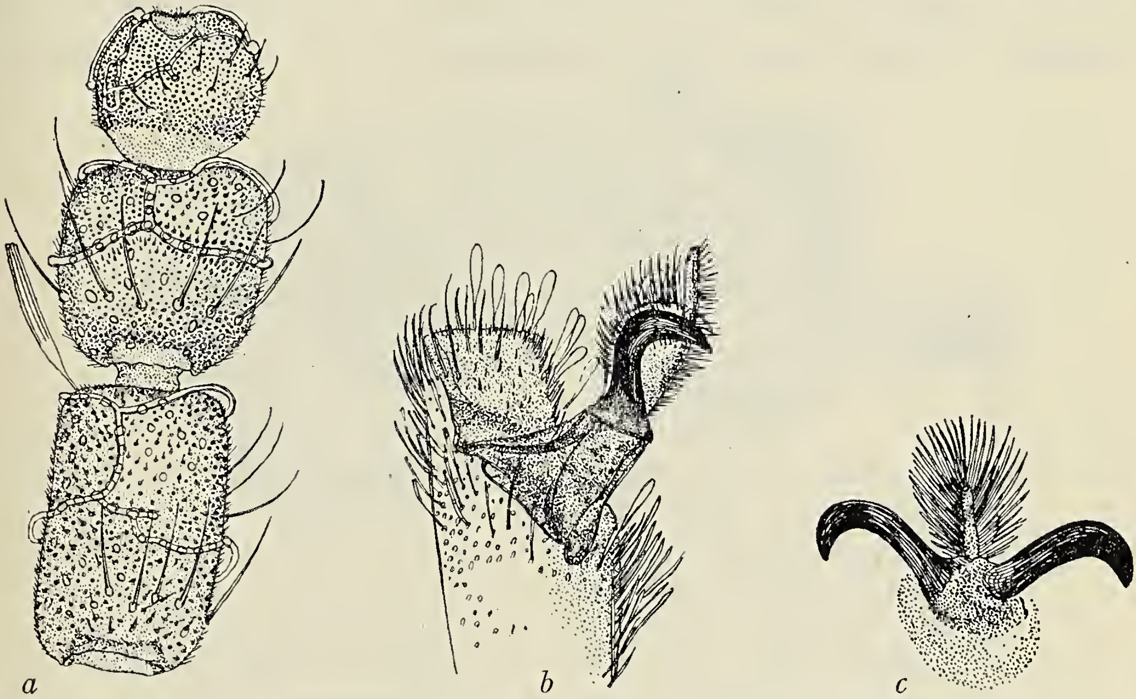

Figure 31 Asphondylia monacha, *a*, distal three antennal segments showing reduction in the terminal ones, *b*, lateral view, and *c*, distal aspect of claws of female (Author's illustration)

Harpes. The harpes are paired submedian organs lying just below the ventral plate. They are usually thicker and in some species at least, have portions of the distal margin greatly thickened, chitinized and recurved to form effective hooks. These organs are generally subquadrate or triangular in outline, shorter than the ventral plate and in some species are thickly clothed with short, stout setae, the distal margin being thickened and irregularly dentate.

Style. This, the intromittent organ, is median and varies greatly in length and shape. It is frequently straight although in some species it may be strongly curved. It also varies greatly in size.

Ventral glands. Certain species of Monardia Kieff. are extremely interesting on account of the submedian, ventral, globose or trumpet-shaped organs (figure 35), presumably orifices of scent glands, on the eighth abdominal segment of the female.

Ovipositor. The terminal abdominal segments in the female are variously modified to form the ovipositor. The organ may be relatively short, the terminal segment bearing a pair of lobes (figure 36) and then oviposition presumably consists simply in the deposition of the eggs upon comparatively smooth surfaces. The seventh, eighth, ninth and tenth segments may be more or less modified in the more highly specialized forms. These segments may simply taper a little to facilitate the greater extension of the ovipositor (figure 37). The seventh and eighth segments may, as in Lasioptera and its allies, bear dorsal submedian, chitinous rods, (figure 38), evidently designed to give the necessary muscular attachment to a somewhat efficient organ. Laterally, on either side of the eighth segment, we may find in Lasioptera, oval groups of specialized scales occasionally accompanied by a few heavy, recurved hooks, (figure 39).

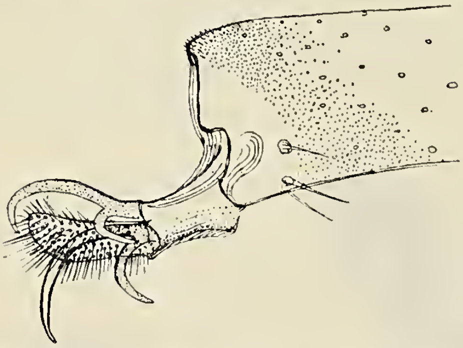

Figure 32 Didactylomyia longimana, lateral view of last tarsal segment showing the toothed claws and the pulvilli of male (Author's illustration)

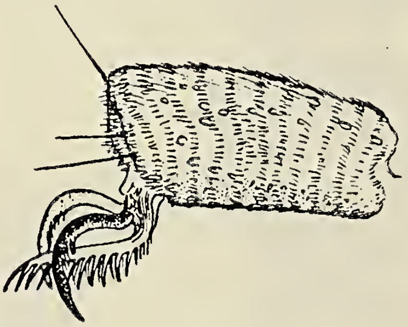

Figure 33 Prionellus leguminicola, side view of distal tarsal segment showing the denticulate claws and the pulvillus in section (Author's illustration)

The ovipositor may have a length equal to or even greater than the body and in some species, consists simply of two distinct segments, the posterior extremely produced and apically with a pair of small, oval or subtriangular, sparsely setose lobes. This type of ovipositor is characteristic of Contarinia Rond. and Dasyneura Rond. The distal portion may become somewhat chitinized as in Schizomyia Kieff. and Thurauia Rübs. (figure 40), a process which is carried still farther in Feltomyia Kieff. and to an extreme in the aciculate terminal portion of Asphondylia H. Lw. (figure 41). This latter is only a greatly developed acicula, as stated below.

The ovipositor, even in those forms possessing an extremely long organ, is ordinarily retracted or partially retracted in the body. This is easily seen in certain species of Asphondylia H. Lw. (figure 42), the slender needle being invaginated in the retracted, thicker basal portion and frequently extending nearly to the base of the abdomen. The same condition prevails in other species having a long ovipositor, except that in the case of those with a flexible, weakly chitinized organ, the structure is more or less coiled within the body of the midge (figure 43).

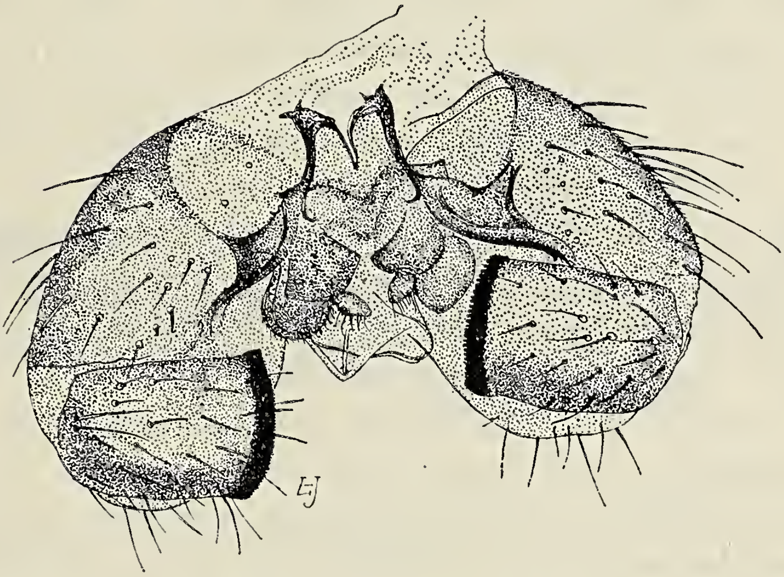

Figure 34 Cincticornia transversa, male genitalia; note in particular the finely serrate chitinous margin of the terminal clasp segment (Author's illustration)

Asphondylia H. Lw. and Schizomyia Kieff. are both interesting because of the special organs found at the base of the eighth abdominal segment, namely the characteristic oval, thickly setose pouch (figure 44) of the former (probably modified and migrant terminal lobes) and the quadrangular ventral plates of the latter (figure 45).

Acicula. This term is applied to a more or less evanescent, chitinous structure frequently found at the base of the distal segment of the ovipositor and evidently of service for muscular attachment. This structure has an expanded, somewhat furcate base and a slender, frequently aciculate shaft. It is well developed in

Sackenomyia Felt (figure 46), Trotteria Kieff., Cincticornia Felt, Monarthropalpus Rübs. (figure 47), Cystiphora Kieff., Feltomyia Kieff., Bruggmanniella Tav. and Schizomyia Kieff. The needle-shaped distal portion of the ovipositor of Asphondylia H. Lw. (figure 41) presumably represents the maximum development of the acicula accompanied by a migration from the base to the tip of the ovipositor.

Terminal lobes. These are tri to uniarticulate, usually sparsely, sometimes densely setose lateral appendages at the tip of the ovipositor, although in Asphondylia H. Lw. these organs appear to be at the base of the ovipositor and have been termed the basal pouch. The terminal segment is usually ovate or sub-triangular. These structures are usually dorsal and apical, although in Winnertzia Kieff. they are subapical (figure 48). They are found in practically all genera except Asphondylia H. Lw. (where they appear in a greatly modified form), and possibly Schizomyia Kieff., Trotteria Kieff., Sackenomyia Felt and Monarthropalpus Rübs., forms apparently able to pierce vegetable tissues with the ovipositor. There is in addition to these two terminal lobes, a similar ventral one, usually triangular and frequently setose like the others.

Tetratology. The fusion of one or more antennal or palpal segments is not uncommon among the Itonididae. For example, a female Monardia lignivora Felt has the tenth and eleventh antennal segments partly fused; an Asteromyia abnormis Felt has the eighth and ninth antennal segments on one antenna fused in much the same way as we find in the third and fourth throughout the Lasiopterariae.

The male of Rhopalomyia abnormis Felt presents a more remarkable condition in that the fifteenth to the nineteenth segments on one antenna are fused to form one long, uniformly haired mass with a length approximately 6 times its diameter. This structure presents a marked contrast to the normal flagellate antennal segments, each with a stem as long as the basal enlargement.

Mycodiplosis captiva Felt shows in one specimen a a curious consolidation on one antenna between the fifth and the sixth segments. The stems separating the two enlargements of the fifth segment and the distal swelling from the basal one of the sixth practically disappear, while the distal enlargement appears as a budlike excrescence between the basal enlargement of the fifth and the sixth segments. The true character of the structure is easily determined by a study of the circumfila.

Kieffer figures an even more remarkable case, a partial or rudimentary dichotomy, in the male antenna of Clinodiplosis, Antichira or

Trichodiplosis caricis Kieff.[1] The ninth antennal segment is normal, while the tenth has its distal enlargement closely fused with the eleventh which latter has no distinct basal enlargement. From the union of the tenth and twelfth, according to Kieffer, there arises at nearly right angles an almost rudimentary eleventh having a subglobular basal enlargement and a pyriform, sessile distal enlargement bearing a conical apex. Rübsaamen[2] illustrates a somewhat similar antennal deformation in the same species.

It is not infrequent to find one or two of the distal antennal segments variably fused with the preceding, thus producing an apparent variation of one or even two segments on the antenna of the same insect. Similar malformations of the palpi frequently occur and due allowance must be made for all such abnormalities.

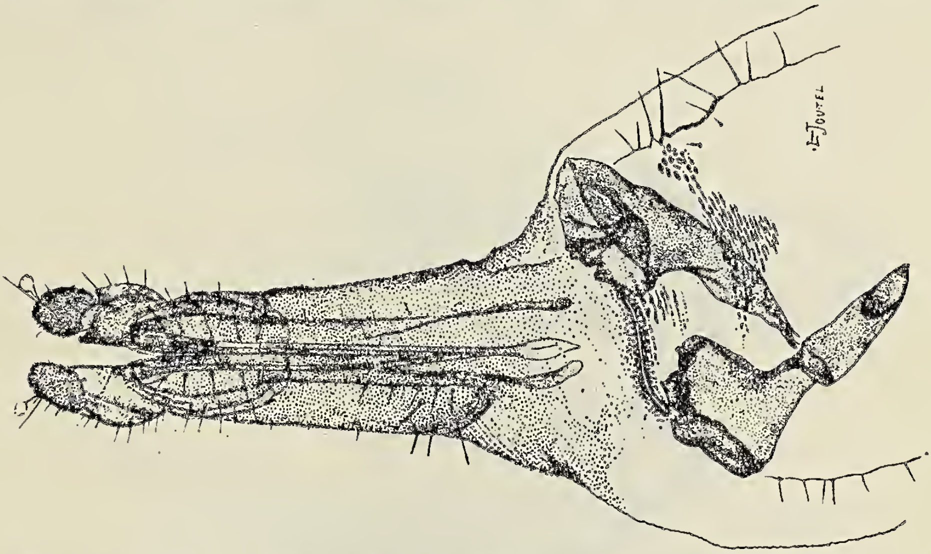

Figure 35 Monardia lignivora, ventral aspect of the tip of the abdomen showing the submedian, funnel-shaped ventral organs and the moderately short ovipositor with its segmented lobes (Author's illustration)

Structure of the pupa. The pupa is generally rather stout and usually whitish or reddish orange, the colors of the midge showing through the semitransparent pupal skin just before the appearance of the adult. This stage is naked as in other Nematocera, the principal body appendages being inclosed in closely fitting sheaths, the antennae, wings and legs being laid against the ventral surface.

Antennal horns. The antennae are among the most conspicuous organs. The segmentation is indistinctly indicated. The most striking modification in these organs is found in the basal segment, which latter is greatly produced at the internal distal angle and

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[1] Ent. Soc. Fr. Ann. 69:257, pl. 18, fig. 7, 1900.

[2] Zeitschr. Wissenschaftl. Insektenbiol. 7:125, 1911.

strongly chitinized in certain species, a structure developed to a marked degree in Asphondylia monacha O. S. (figure 49)., Sackenomyia porterae Ckll. and S. packardi Felt. It appears to be characteristic of Asphondylia H. Lw. though the segment is only slightly produced and chitinized in Schizomyia pomum Walsh, while in Cincticornia sobrina Felt there is practically no extension and chitinization of this segment. Similarly, we find but a slight production and chitinization of this segment in Sackenomyia viburnifolia Felt, due probably to the fact that this species develops in leaves, while its allies are found in willow stems. This segment is slightly produced and feebly chitinized in Lasioptera clarkei Felt and the same is true of Caryomyia inanis Felt.

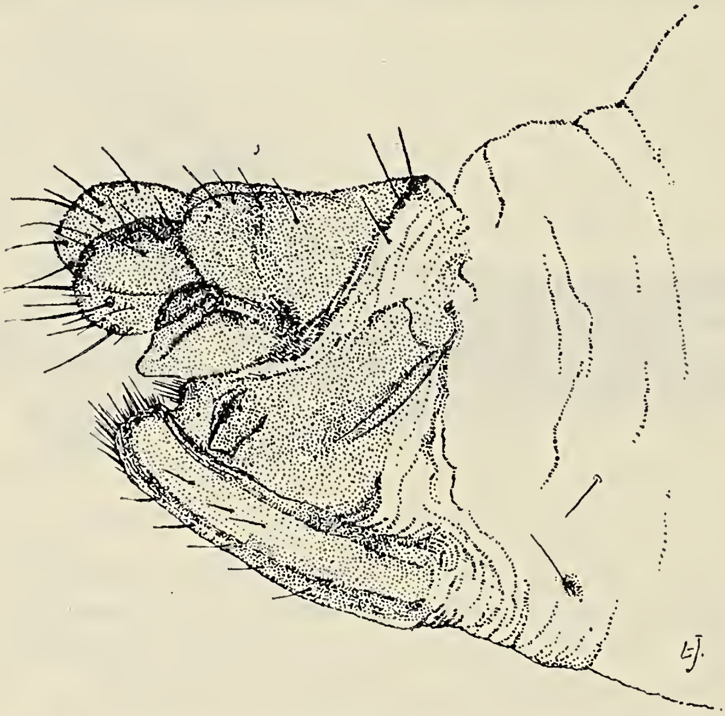

Figure 36 Colpodia terrena, lateral view of the apex of the abdomen and ovipositor (Author's illustration)

Thoracic horns. This designation is applied to the submedian, chitinous respiratory organs arising from near the anterior extremity of the pupa. They vary greatly in development and are extremely long and filiform in Monardia lignivora Felt, having a length nearly equal to the diameter of the pupa. They are long, stout, tapering and chitinized in such species as Sackenomyia viburnifolia Felt, Schizomyia pomum Walsh and presumably many others which have the first antennal segment but slightly produced and weakly chitinized. It is interesting to note that those forms mentioned above as having the basal antennal segment greatly produced and strongly chitinized, have relatively weak thoracic horns, indicating a probable correlation between the development of the two structures.

Wings. The wings are inclosed in oval pads, lie against the ventral surface of the body and extend to about the second or third abdominal segment.

Legs. The legs, like the wings, are inclosed in cases and folded against the ventral surface of the body.

Abdomen. The segmentation is visible, the general shape and structure being much as in the adult. In well-advanced pupae at least, it is easy to distinguish the sexes.

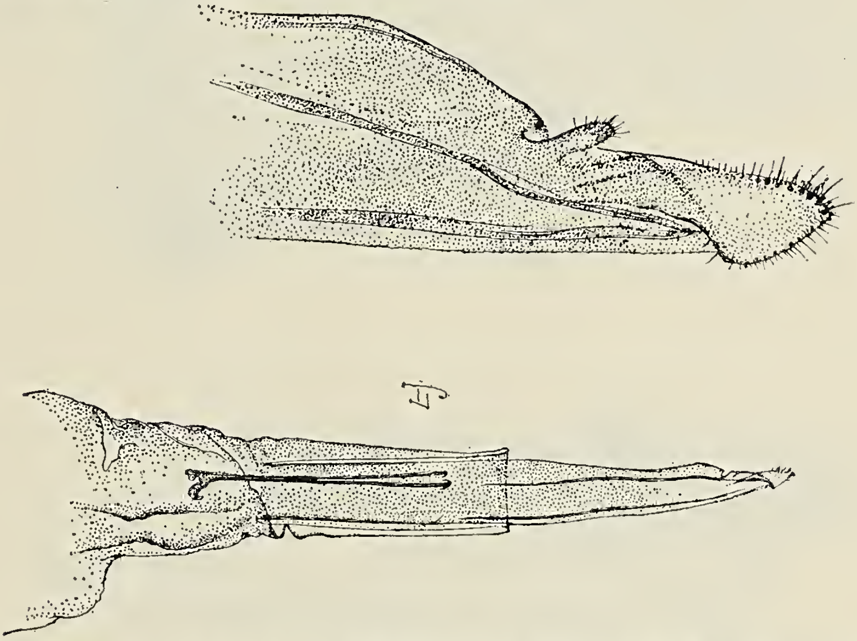

Figure 37 Rhabdophaga marginata, ovipositor partly extended and the tip more enlarged .(Author's illustration)

Dorsal spines. The pupae of Asphondylia H. Lw. are easily recognized by the series of irregular, transverse rows of unusually large spines on the dorsum of each abdominal segment, the posterior row being markedly stouter in Asphondylia monacha O. S. In Schizomyia pomum Walsh the spines resemble those of Asphondylia, except that the posterior row is decidedly longer. The pupae of Cincticornia sobrina Felt are easily separated from Asphondylia by the spines being uniform in size. The anterior half of the abdominal segments is uniformly spined in Caryomyia inanis Felt, while Thecodiplosis liriodendri O. S. has a scattering row of spines near the anterior third of each segment, a condition very similar to that presented by the pupa of Itonida tecomiae Felt.

Skin. The skin of the abdomen, aside from the spines noted above, may be nearly smooth, thickly clothed with fine spines or coarsely shagreened, the latter appearing to be characteristic of Asphondylia H. Lw. and Caryomyia Felt.

There are a number of other structures upon the pupae which could undoubtedly be studied to advantage if one possessed representatives of many of the genera. Kieffer has described cervical, facial, thoracic, dorsal and lateral papillae, abdominal warts and several other structures. Our material has not been sufficiently abundant to work this out in detail.

Structure of the larva. The larva is usually moderately stout to broadly oval and is composed of fourteen segments, namely, the head, the supernumerary segment just behind, three thoracic segments and nine abdominal segments.

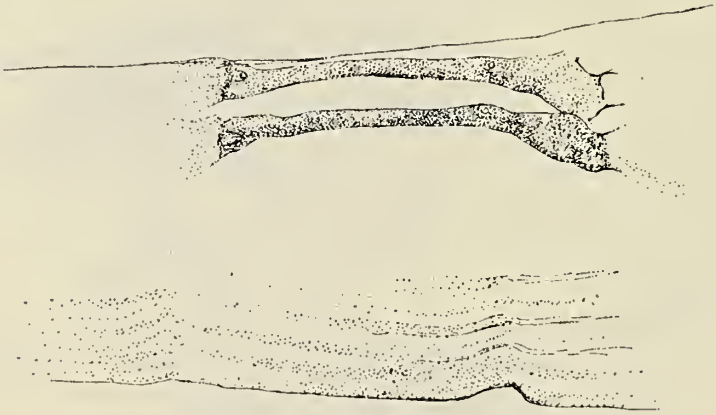

Figure 38 Lasioptera neofusca, basal portion of ovipositor showing the dorsal chitinous bars (Author's illustration)

Head. The head is usually small, weakly chitinized, generally triangular in shape and bears near the lateral dorsal angles, small, uniarticulate or biarticulate palpi. In some predaceous forms the head and the antennae may be greatly produced.

Breastbone. This structure, known as the " anchor process " in England, is found only in the Itonididae and it frequently affords one of the readiest means of recognizing larvae of this family. It varies greatly in development and shape and appears to be obsolete or nearly so in certain forms and very heavily chitinized in others. The typical breastbone is composed of a chitinized, subcutaneou shaft having a length approximately half that of the diameter of the body and terminating in a free anterior extremity, which latter may be unidentate, bidentate, feebly or strongly tridentate or, in Sackenomyia packardi Felt, greatly dilated laterally and multidentate (figure 50). A number of species of Asphondylia are easily recognized because of the quadridentate breastbone, while certain Caryomyias may be identified by the unidentate breastbone.

There is a remarkable structure on the first thoracic segment of the larva of Lasiopteryx flavotibialis Felt. The ventral anterior margin is somewhat chitinized and supports a median, subquadrate, slightly bidentate process appearing much like a short, misplaced breastbone and, in addition, there arises from the base of the structure a pair of long, stout, diverging, chitinous processes, all extending posteriorly (figure 51). This structure was substantially identical in two larvae and can hardly be considered a malformation. It may aid in locomotion, since the larvae occur in partly decayed vegetable matter.

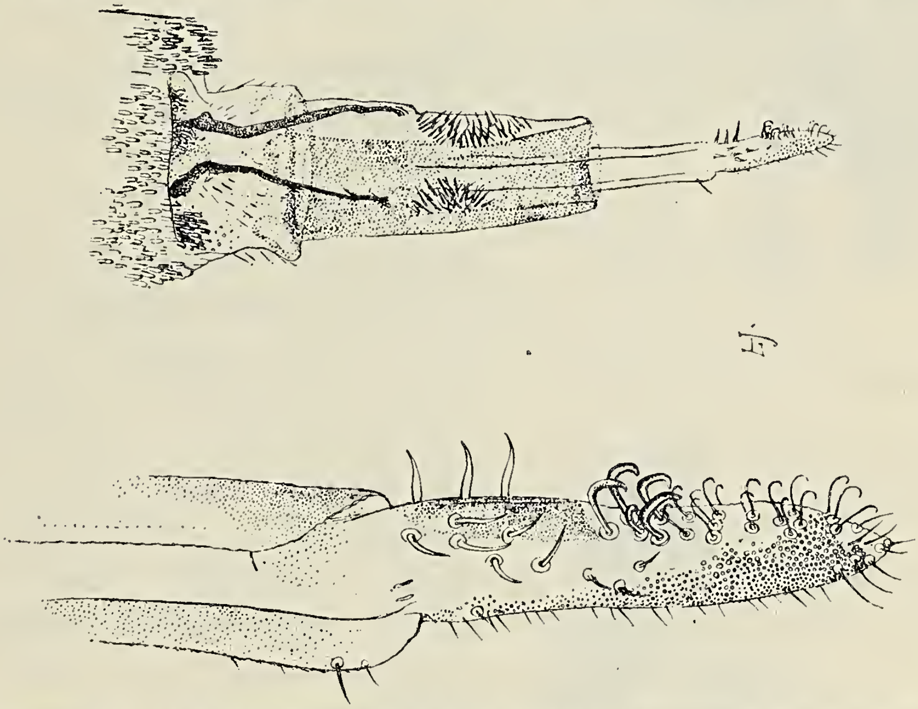

Figure 39 Lasioptera serotina, terminal abdominal segments showing the ovipositor and the tip of the latter bearing its groups of chitinous hooks still more enlarged (Author's illustration)

Body segments. The thoracic and abdominal segments are nearly uniform in appearance, usually of the same size, minute spiracles occurring upon the first thoracic segment, the first to seventh and the ninth abdominal segments. The skin may be nearly smooth, finely or coarsely shagreened. The term ocular spot is applied to an irregular, obscurely defined, reddish or brownish lobed body lying in the second or third segment above the esophagus and salivary glands. Kieffer and his associates, as a result of their studies of the larva, have defined several types of warts, namely, circular, spined, granular and hooks. The last are chitinous, movable, arranged transversely and bear apically claws which, in the case of the larva of Rhizomyia circumspinosa Rubs. are crescent-shaped. The American Cecidomyia viticola O. S. bears on its bilobed posterior extremity, irregular series of conical teeth, they and their supports functioning as a prehensile organ.

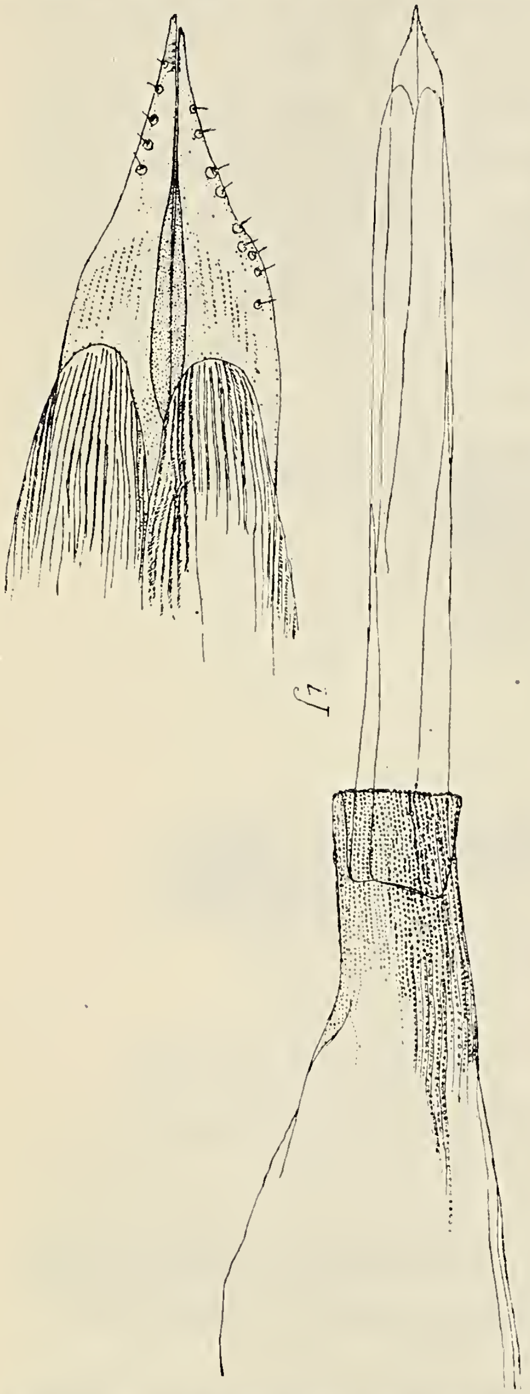

Figure 40 Thurauia aquatica, ovipositor of female nearly extended and its tip still more enlarged (Author's illustration)

Minute papillae may also occur upon the body surface. These have been discussed by Kieffer under subheads as cephalic, cervical, sternal, internal, lateral and ventral papillae. These extremely minute structures are discerned only with great difficulty and, as far as our experience goes, are hardly available for generic or specific reference, aside possibly from those forms living unprotected and therefore usually with better developed papillae and setae. The general arrangement of these organs is in more or less regular transverse rows. Larvae belonging to certain genera, such as Lestodiplosis Kieff. and Arthrocnodax Rubs., have prolonged ventral appendages which may well be designated as pseudopods. They occur near the anterior third of the segment and in the case of Lestodiplosis peruviana Felt are present on the second to tenth abdominal segments. There are, in certain species, at the posterior extremity, a pair of submedian chitinous processes (figure 52), presumably homologous with the pseudopods noticed above.

Taxonomy

The wings, tarsi and antennae afford excellent characters for the separation and grouping of subfamilies and tribes. The number of veins, the relative degree of reduction and especially the presence or absence of the crossvein uniting subcosta with the third, are of great importance. The vestiture of the anterior or costal vein is characteristic in certain groups. The number of tarsal segments, the relative length of the first segment or metatarsus, and the structure of the claws, simple or toothed, are of much service in determining relationships.

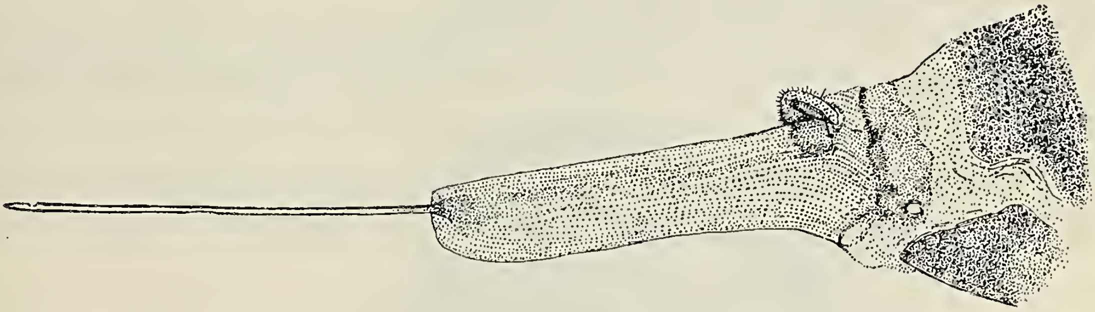

Figure 41 Asphondylia monacha, lateral view of ovipositor, note the dorsal basal pouch, the thickened basal portion of the ovipositor and the slender aciculate part (Author's illustration)

There is a strong tendency among Itonididae toward reduction in the appendages. This modification is most apparent in the antennae. The number of segments is most generally fourteen. Microcerata Felt. Joannisia Kieff., Clinorhyncha H. Lw., Arnoldia Kieff. and Asphondylia H. Lw., all show marked reduction either in the number of segments or in the length of certain segments. On the other hand, many forms have developed in the opposite direction and may either have the normal number of segments with the individual arthromeres greatly produced or there may be a great multiplication in the number of segments and a comparatively slight increase in the length of individual segments.

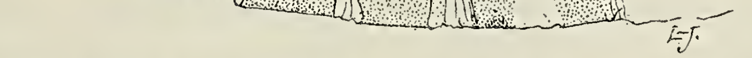

Figure 42 Asphondylia arizonensis, side view of abdomen showing the ovipositor retracted (Author's illustration)

There is a similar tendency toward reduction in palpal segments. The first, the second, the third and in a few instances even the fourth or last segments have disappeared. The wide spread tendency toward reduction in the number of the palpal segments is shown by its occurrence in all tribes, except possibly the Lestremiinariae.

There are also great variations in the wings. It is only necessary to compare the organs of flight in Lestremia with those of Porricondyla, Lasioptera and Heteropeza to see at a glance the extent to which these organs have been modified.

Similarly, the tarsi are subject to reduction, only a few members of this large family possessing all the tarsal segments unmodified. Reduction begins with the first segment or metatarsus and in the great majority of species, all the Itonididinae, this segment is perhaps less than one-fourth its normal length. The process of tarsal reduction has been carried to extremes in the Heteropezinae, the first, the second and even the third segments having disappeared and leaving only the fourth and fifth functional in a few greatly modified forms.

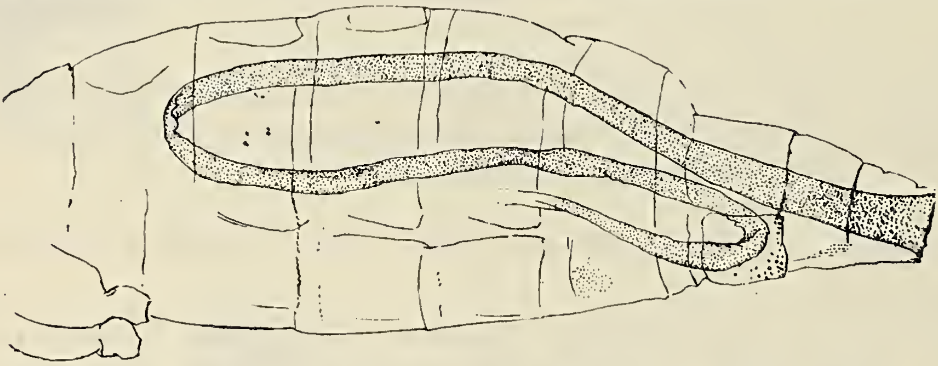

Figure 43 Xylodiplosis aestivalis, side view of abdomen showing the extremely long, slender ovipositor retracted and partly coiled within the abdomen (Author's illustration)

These structural modifications are significant, although their meaning may not be apparent. They are usually accompanied by other changes and in not a few instances are correlated with food habits.

Lestremiinae

The Lestremiinae are undoubtedly the more generalized members of the family. The genera included therein are easily recognized by the presence of at least four veins, five tarsal segments, and by the metatarsus being distinctly longer than the following segment. Lestremia with its well-marked crossvein and Sciara-like fork of the fourth vein, is evidently not far removed from the Mycetophilidae, although it may be readily separated therefrom by the absence of tibial spurs and by the coxae not being greatly produced. The antennal segments of this genus exhibit a distinctly higher degree of specialization than occurs in the Mycetophilidae. The antennae of the Lestremiinae and Heteropezinae may be at once distinguished from those of the Itonididinae by the absence of circumfila. The two lower subfamilies, judging from our knowledge of their habits and the sensory structures of the antennae and palpi, appear to depend largely upon the olfactory organs, while the Itonididinae with their peculiar and frequently highly developed circumfila seem to rely mostly upon the auditory sense.

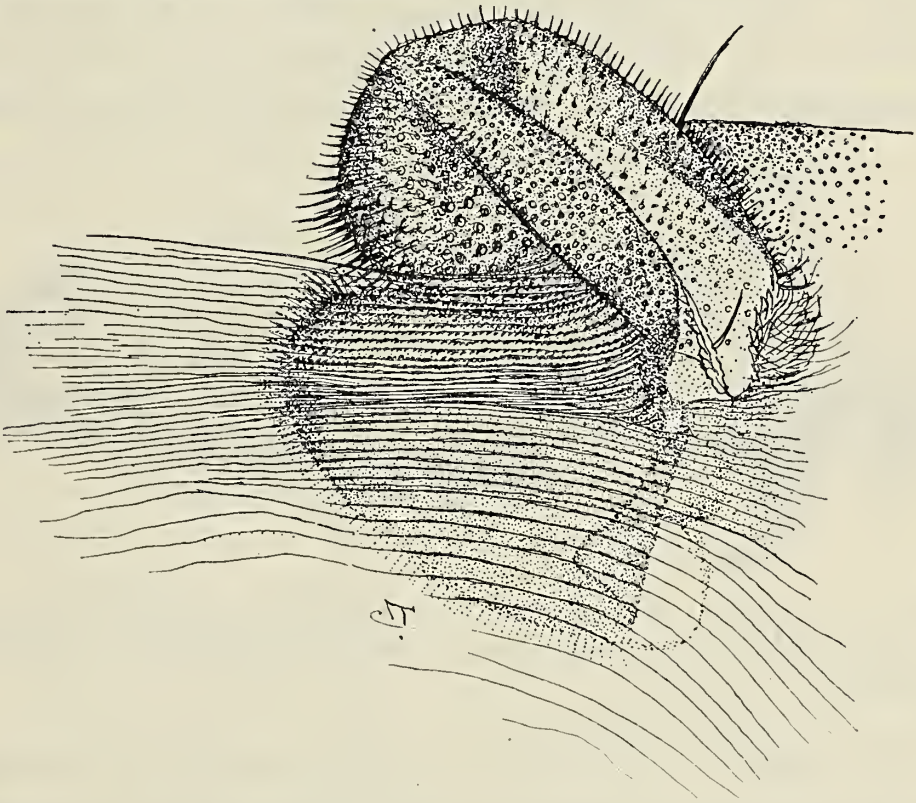

Figure 44 Asphondylia monacha, dorsal pouch at the base of the ovipositor (Author's illustration)

The genera Lestremia Macq. and Catocha Hal. both have the antennae moderately developed with eleven to sixteen segments and are among the most generalized of the gall midges. The venation of Lestremia approximates that of the Mycetophilid genus Sciara with its characteristic fork of the fourth vein. The genitalia is comparatively simple and characteristic. The genus Catocha Hal. is easily separated from the preceding by costa being continuous and extending beyond the apex of the wing and furthermore by the much shorter fork of the fourth vein. It is distinctly a more specialized form and the probabilities are that the genus as at present recognized should be subdivided.

The other genera of the Lestremiinariae have greatly reduced antennae, there being only eight to ten or eleven segments. Microcerata Felt is easily distinguished by the greatly enlarged second antennal segment, the very short flagellate segments and the distinct union between subcosta and the third vein in connection with the rudimentary forked fourth vein (figure 53). This genus has only eight or nine antennal segments in the male and ten in the female, the palpi being nearly as long as the antennae.

Two other genera of minute flies, namely Konisomyia Felt and Tritozyga H. Lw., are distinguished from Microcerata Felt by subcosta and the third vein being separate and not united by a crossvein. The two genera are closely allied, the former being characterized by the even fork of the fourth vein while the latter is peculiar on account of the irregular or uneven branches, the posterior fork being nearly a continuation of the basal part of the vein while the anterior appears to have migrated and is distinctly asymmetrical.

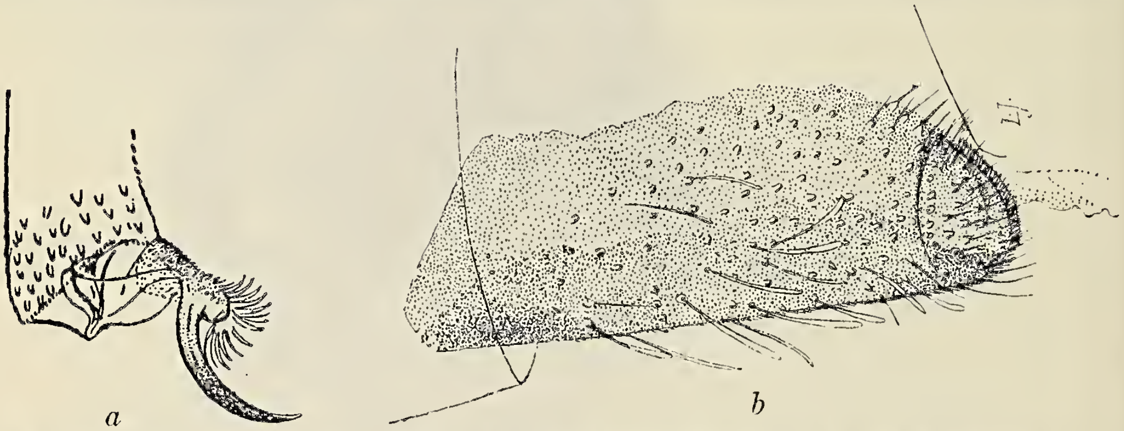

Figure 45 Schizomyia rubi, *a*, lateral aspect of the distal portion of the last tarsal segment and claw, *b*, ventral plate of female (Author's illustration)

The three preceding genera have the second antennal segment greatly enlarged, while in the two following it is of normal size. The genus Neptunimyia Felt has the flagellate antennal segments of normal length and in the type species they bear series of digitate sensory organs. Neocatocha Felt is remarkable for a venation identical with that of Catocha Hal. while the greatly reduced antennae approach conditions found in Konisomyia Felt, the flagellate segments bearing a series of irregular cylindrical or conical sensory organs.

The fossil Lithomyza Scudd. from White River, Colo., appears to be closely allied to Lestremia Macq. while its short nine-jointed antennae indicate a close affinity with Tritozyga O. S. It is, if correctly placed, one of the most generalized Itonids and may be regarded as a connecting link between this group and the Mycetophilidae.

The tribe Campylomyzariae may be derived from a Lestremia-like ancestry, although presenting a considerably higher degree of specialization in the wings, antennae and genitalia. The reduction of the Sciara-like fork, so well advanced in Catocha, has been continued so that the fourth vein in this tribe is represented only by a weak line of chitin. There is comparatively slight modification of the third vein or of subcosta. The most generalized genera in this group are doubtless the European Strobliella Kieff., Wasmanniella Kieff., and Pegomyia Kieff., all distinguished by the simple fifth vein.

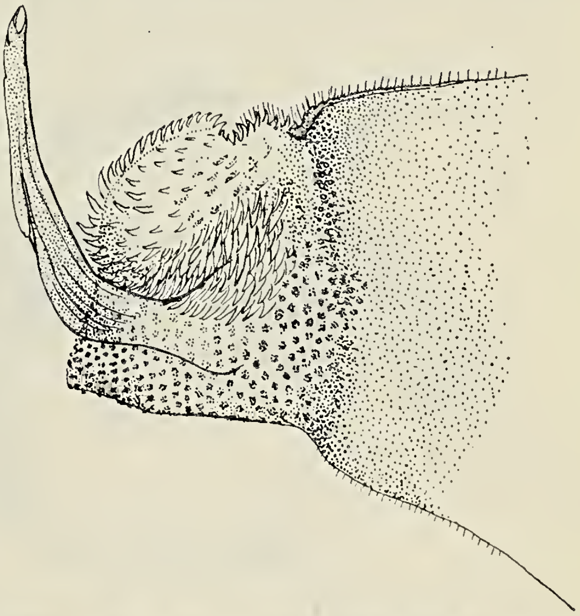
Figure 46 Sackenomyia acerifolia, lateral view of tip of abdomen and ovipositor (Author's illustration)

A series of comparatively generalized forms is represented by Joannisia Kieff., genera easily recognized by the third vein being usually well separated from costa and frequently uniting therewith at or beyond the apex of the wing. The stemmed flagellate antennal segments have globose enlargements ornamented only with irregular whorls of long hairs. These latter present a striking contrast to the somewhat highly developed crenulate whorls of Campylomyza and its allies. Joannisia Kieff. shows the beginning of palpal reduction, these organs being quardriarticulate or triarticulate, while in the European Peromyia Kieff. they are biarticulate and the claws are strongly curved and dilated subapically. The American genus Mycophila Felt is closely related to Joannisia Kieff. from which it is easily separated by the cylindrical shape of the basal enlargement of the flagellate antennal segments. A somewhat higher degree of specialization is indicated by the moderately regular setal arrangement and the apparently greatly reduced palpi. The European Xylopriona Kieff. has the basal enlargement of the flagellate antennal segments transverse, that is, the diameter is greater than the length, and the genus is peculiar in this series because of the presence of stemmed disks. Tetraxyphus Kieff. shows specialization in the increased number of antennal segments, there being eighteen and the whorl of awl-shaped appendages, both characteristics which serve to distinguish it from the American Mycophila Felt.

The remainder of the genera in this tribe are more specialized since the third vein does not extend to the apex of the wing and the sensory organs on the antennal segments are decidedly complex, the peculiar structures known as crenulate whorls being characteristic of this group. Micromyia Rond. has antennae suggesting those of Tritozyga H. Lw. and Konisomyia Felt, they being greatly reduced and having only six to eight segments in the female and ten or eleven in the male, the second segment being enlarged and globose. The other genera in this division have a larger number of antennal segments, usually sixteen or more, have much in common with each other and may with few exceptions be grouped under what is apparently a supergeneric division, namely Campylomyza Meign., the genera being separable only with difficulty and on comparatively minor variations with the exception of the unique Cordylomyia Felt and Corinthomyia Felt, both of these presenting antennal characters apparently not found elsewhere, the female of the former has a thick subapical whorl of short, stout, curved, conical spines (figure 13) on the flagellate antennal segments, while the latter presents a remarkable modification of the crenulate whorl in a series of extremely regular, beautiful whorls of rather stout, curved,

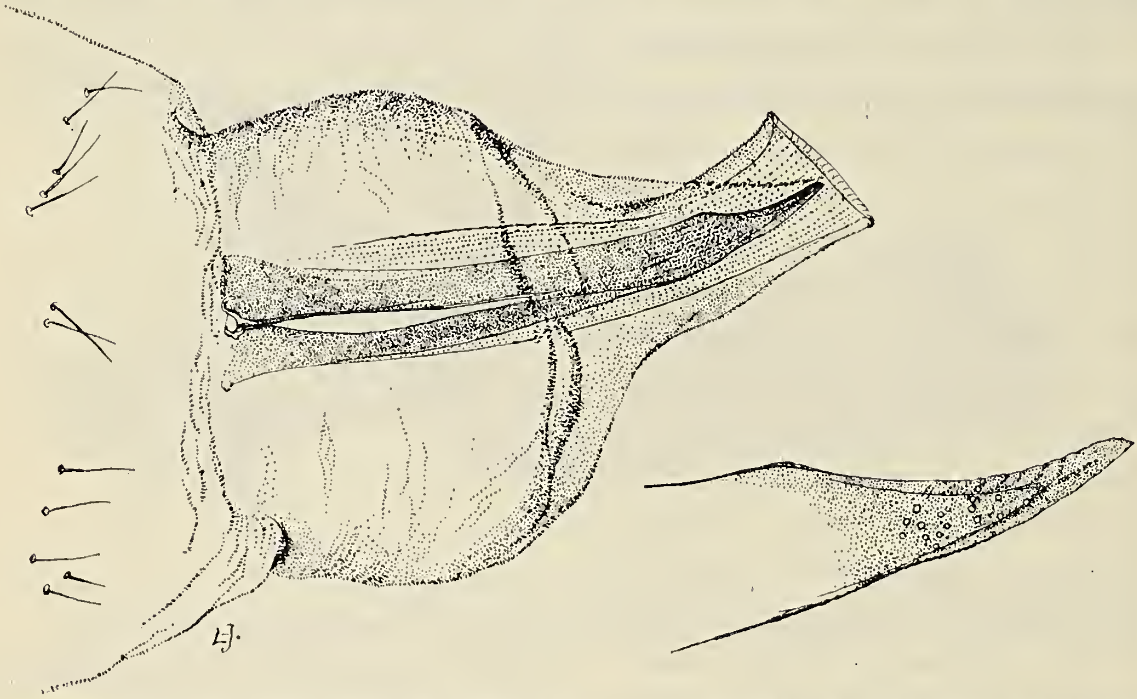

Figure 47 Sackenomyia packardi, lateral view of tip of abdomen showing the distal portion of the ovipositor retracted within the body of the female and also the tip of the ovipositor more enlarged (Author's illustration)

scarcely tapering setae or spines (figure 12) arranged in five or six parallel series.

Heteropezinae

The Heteropezinae, one of the oldest and possibly the most decadent group of the gall midges, comprise what at first might be regarded as a heterogeneous assembly of unrelated forms. A study of all characters shows the genera referred to this family agree with the Lestremiinae in being without circumfila, although the forms placed here frequently resemble in a general way the Itonididinae. The well-developed crossvein uniting subcosta and the third vein in the Lestremiinae is absent in most Heteropezinae, a marked exception being found in the synthetic Johnsonomyia Felt, and the apparently closely related Necrophlebia Skuse and Chastomera Skuse of Australia. A number of genera are characterized by great reduction in venation, tarsi and palpi and also present astonishing variations in these organs.

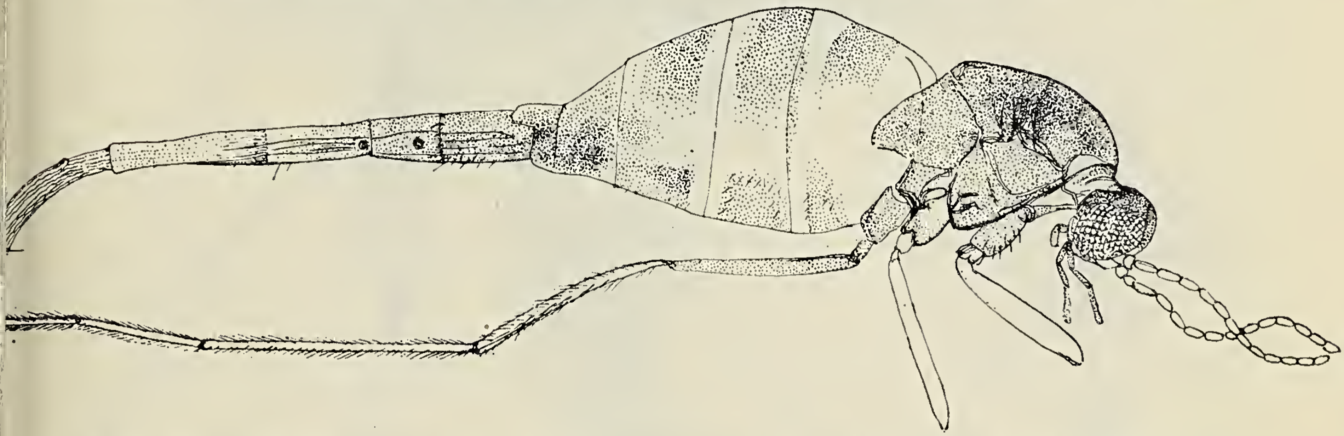

Figure 48 Winnertzia calciequina, side view of female with extended ovipositor, the wings and a portion of the legs not being represented, note the subapical lobes of the ovipositor (Author's illustration)

The more generalized in this subfamily have the metatarsus longer than the second segment and the tarsi quadriarticulate. The oldest of these is probably the amber Meunieria Kieff. with its three long veins and quadriarticulate palpi, while the ancient Palaeospaniocera Meun. with its triarticulate palpi may be placed next. The remarkable Neostenoptera Meun. from the Copal has but one long vein and is most interesting because the flagellate antennal segments seem to approach closely the condition found in Johnsonomyia Felt. Miastor Mein. has biarticulate palpi and appears to be widely distributed, though it is usually overlooked on account of its somewhat peculiar habitat. Peromiastor Kieff. is distinguished by the uniarticulate palpi.

Two genera, Heteropeza Winn. and Monodicrana H. Lw., are separated from the preceding by the triarticulate palpi and the two long veins, the former has cylindric antennal segments and is a living genus, the latter with globose antennal segments and is known only from the amber.

The remaining members of the Heteropezinae are distinguished by the metatarsus being shorter than the second segment. Most of these genera have the tarsi quinquearticulate and they may be divided into series having the wing membrance finely haired, represented by Haplusia Karsch and Johnsonomyia Felt, the former with the fifth vein forked, the latter with it simple and both with quadriarticulate palpi and the third vein extending to the apex of the wing. Johnsonomyia Felt is a remarkable synthetic form on account of the long setae on the antennal segments approximating the crenulate whorls in Campylomyza Meign. while the venation, the crossvein (plate 1, figure 6) being well developed, would lead one to place the insect in the Porricondylariae. The peculiar Meinertomyia Felt is distinguished from the two preceding by the triarticulate palpi and the acuminate wings and Leptosyna Kieff. by the uniarticulate palpi and the wings being acute apically. The other genera, Frirenia Kieff. and Epimyia Felt (figure 54) and Gioliella DelGuer., the first

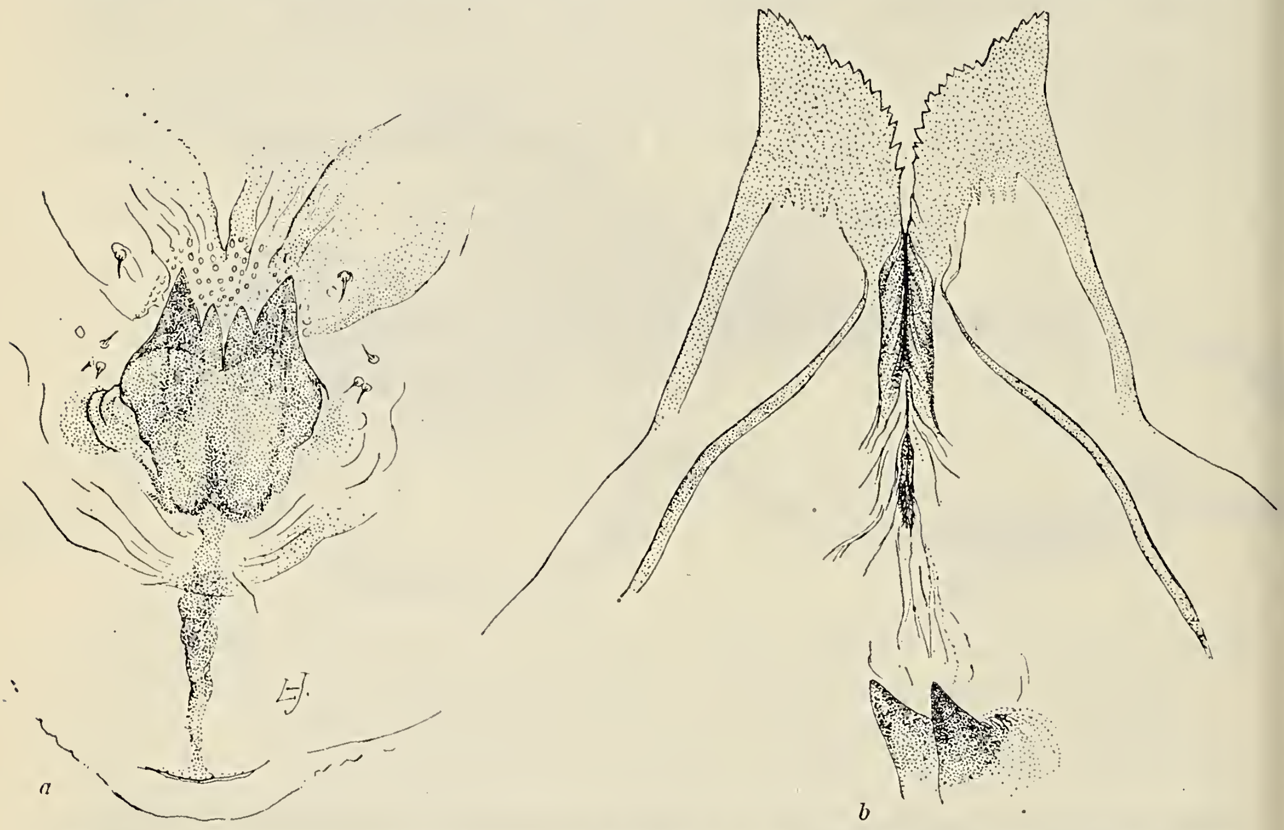

Figure 49 Asphondylia monacha, *a*, quadridentate breastbone of larva, *b*, cephalic horns of pupa (Author's illustration)

with palpi biarticulate and the latter with triarticulate palpi may be separated from the preceding by the third vein not extending to the apex of the wing.

The series having the wing membrane scaled is represented by Ledomyiella Meun., an amber form having the fifth vein forked and the palpi quadriarticulate and the modern Kronomyia Felt and Brachyneura Rond., the former with four simple long veins and biarticulate palpi and the latter with three simple long veins and triarticulate palpi.

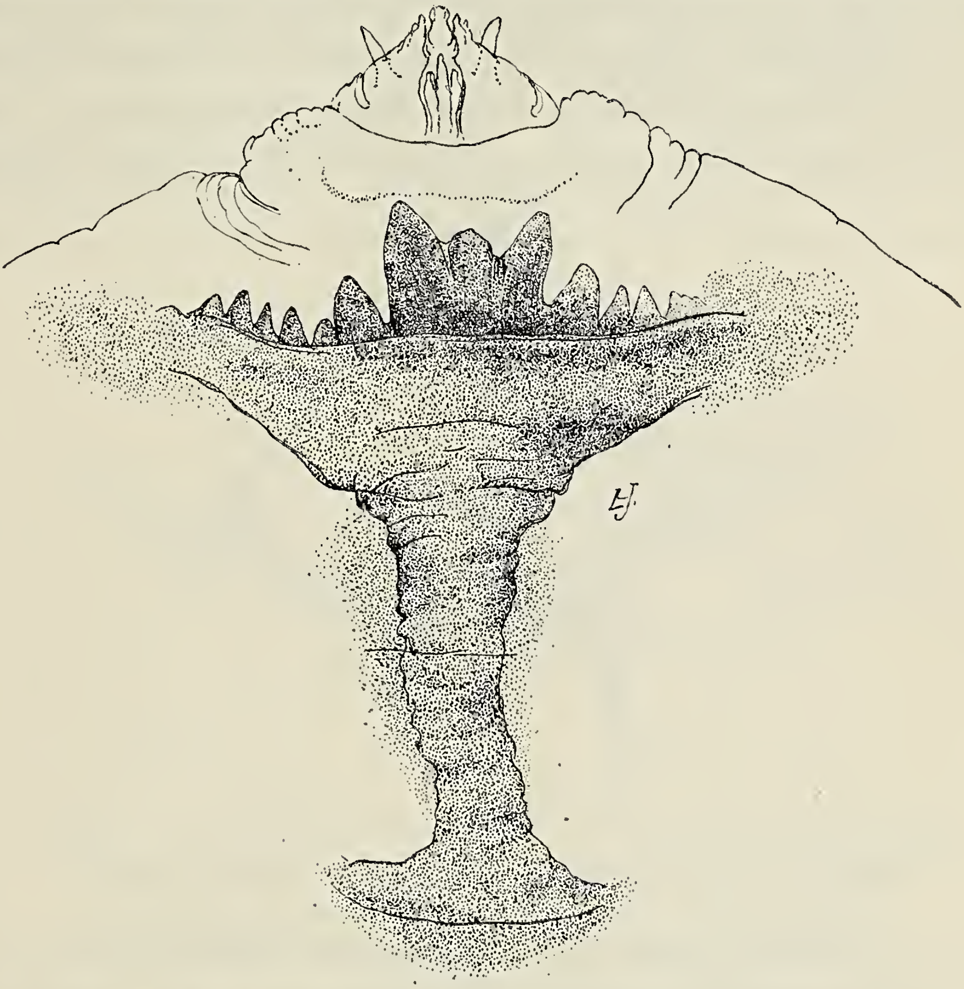

Figure 50 Sackenomyia packardi, ventral view of larval head and the multidentate breastbone (Author's illustration)

Oligarces Mein., with its biarticulate tarsi, rudimentary mouth parts and usually simple veins, exhibits the highest degree of specialization by reduction and on this account is placed at the end of the series.

Itonididinae

The remaining subfamily, Itonididinae, comprises by far the largest number of species and includes practically all the gall-making forms. Species placed here always have the metatarsus shorter than the following segments and the wings have three or four long veins. The subfamily is further characterized by the usual presence of circumfila, auditory structures varying widely in development and apparently performing an important function.

Porricondylariae

The tribe Porricondylariae is easily recognized by the distinct crossvein uniting the third vein and subcosta (plate 1, figures 4, 6, 8, 9), a structure indicating a relationship to the Lestremiinae, specially the Campylomyzariae, a conclusion supported by a study of the food habits, since members of both of these tribes appear to breed for the most part at least in decaying vegetable tissues. The position or direction of the characteristic crossvein apparently possesses considerable significance and at the outset the tribe is divided into those having the crossvein not parallel with costa and therefore forming a well-marked angle therewith, a condition well exemplified in the generalized Winnertzia Rond. (plate 1, figure 8) with its crossvein having a direction approximately intermediate between what obtains in Campylomyza Rond. and Porricondyla Rond. The antennae of Winnertzia Rond. (figure 27) are peculiar on account of the remarkable circumfila which appear very much like small horseshoes nailed to opposite sides of each segment, the free ends projecting beyond the enlargement. The recently dis-

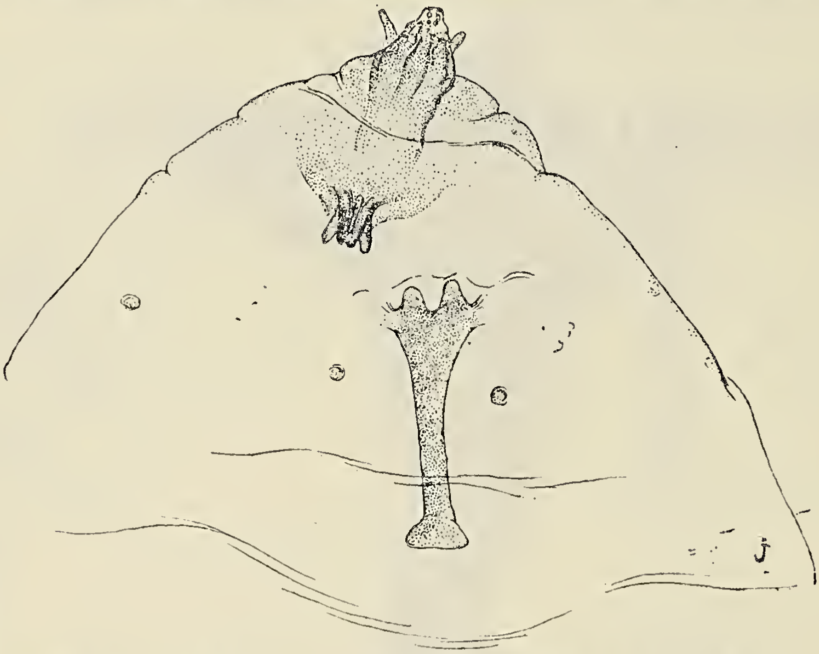

Figure 51 Lasiopteryx flavotibialis, ventral aspect of anterior segments of larva showing the head, peculiar structure just behind the head and the breastbone (Author's illustration)

covered Parwinnertzia Felt differs from the much better known Winnertzia Rond. by the absence of the fifth vein and the reduction of the palpi to biarticulate organs. The peculiar Diallactes Kieff. is related to Winnertzia Rond. from which it is easily separated by the fifth vein arising from the third near the crossvein and the presence of a supernumerary vein at the basal third of subcosta. The Australian Gonioclema Skuse appears to be closely allied to Winnertzia Rond. though easily distinguished by the fifth vein being obsolete basally and apically. The genera mentioned above all have four long veins (rarely three), the fifth vein simple (rarely wanting) and the sixth vein free.

A distinct advance in specialization is exhibited in the remaining subdivision in which there are but three long veins, the sixth being a branch of the fifth or wanting. The first subdivision have moderately long, broad wings with the crossvein at an oblique angle to costa and are well represented by the American Didactylomyia Felt and Colomyia Kieff., the former having the fifth vein forked and remarkable because of the extremely produced and slender terminal clasp segment, the latter with the fifth vein simple and the sixth wanting, and the palpi biarticulate.[1] Two South American genera, Liebeliola Kieff. & Jorg. and Alexomyia Felt are placed here and may be most easily distinguished by the supernumerary vein at the base of costa. Other modifications in this group are outlined in the table for the separation of the genera. The more highly specialized in this division are remarkable for the unusually

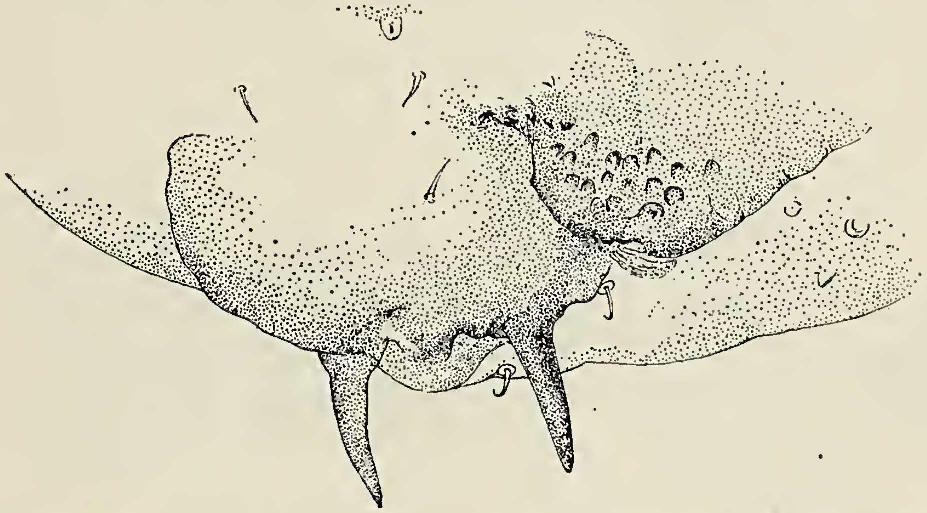

Figure 52 Schizomyia pomum, posterior extremity of larva showing the prominent processes (Author's illustration)

long, narrow wings, foreshadowed in the preceding group and the position of the cross vein, it being almost at right angles to costa. Colpodia Winn. is a common and widely distributed genus belonging here (figure 55). The European Clinophaena Kieff. is distinguished from Colpodia Winn. by the simple fifth vein not extending to the margin of the wing while the fossil Paleocolpodia Meun. has a simple fifth vein, the sixth wanting.

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[1] The superficial characters of Johnsonomyia Felt would place it next this genus from which it is easily separated by the quadriarticulate palpi. It belongs as stated earlier with the Heteropezinae owing to the absence of circumfila.

The remainder of the tribe Porricondylariae may be easily recognized by the crossvein being parallel or nearly so with costa (plate 1, fig. 9) and apparently forming a continuation of the third vein. Asynapta H. Lw., with its simple fifth and sixth veins and numerous long antennal segments, is one of the more generalized forms. The European Clinorhytis Kieff. is closely related and may be distinguished by the smaller number of antennal segments, the simple claws with shorter pulvilli and the triarticulate ovipositor. Rubsaamenia Kieff. is another near ally characterized by the more slender abdomen with its distal portion recurved dorsally. The peculiar Dicerura Kieff. has a greatly produced abdomen, it having a length

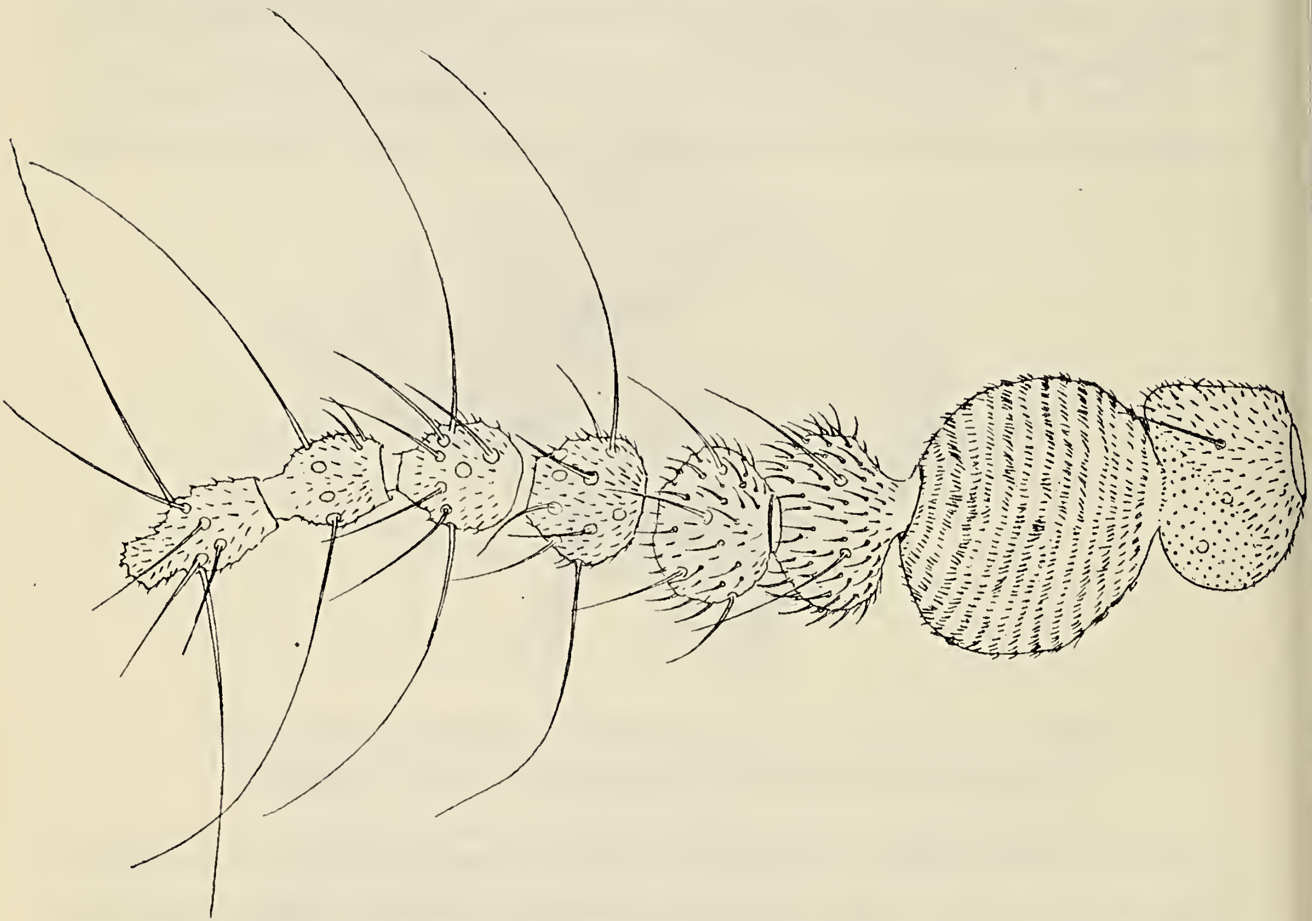

Figure 53 Microcerata johnsoni, antenna of male showing the small number of relatively insignificant segments; these organs are hardly as long as the palpi (Author's illustration)

3 times the remainder of the body and it is further distinguished by the simple fifth vein being obsolete basally.

The remaining genera in this group have the fifth vein forked or simple, the latter indicating a complete disappearance of the sixth. Porricondyla Rond. with its greatly produced antennae, is characteristic of this division. The genus has been subdivided by Kieffer. The genera are probably valid, although distinguished by minor variations. Here, as in the preceding group, we have a genus, Camptomyia Kieff., separated from the others by the long, slender abdomen, the distal portion being recurved dorsally. The preceding group of genera have the antennal segments greatly produced in the male or at least with a distinct stem, while those following in the series with quadriarticulate palpi have the antennal segments approximately equally produced in both sexes. The genus Dirhiza H. Lw. presents, in the American forms at least, peculiar characteristics which greatly facilitate its recognition though they are not easily formulated. Prodirhiza Kieff. appears to be closely related to Dirhiza. The African Lopeziella Tav. may be distinguished from the preceding by its triarticulate palpi.

The African Lopezia Rubs. and the South American Allodiplosis Kieff. and Jorg., provisionally associated with the preceding, present a most remarkable combination of characteristics since they have a distinct crossvein nearly parallel with costa and the flagellate antennal segments of the male provided with circumfilar loops as in the Itonididinariae, the former with quadriarticulate and the latter with uniarticulate palpi. The presence of highly specialized circumfila in this group is extremely interesting and if the genera are correctly placed would indicate specialization along parallel lines. The same would be true if later investigations were to show that these two genera belonged in the Itonididinariae, except that the specialization would be in the retention of the crossvein instead of the development of the circumfila.

The two following genera are distinguished from the preceding by the fifth vein being simple, the sixth wanting. Holoneurus Kieff. is separated by the pulvilli being at most twice as long as the denticulate claws, while Coccopsis Meij. has toothed claws which are more than twice the length of the pulvilli. Hormosomyia Felt is unique in the Itonididinae on account of the five long veins, the distal part of the simple fourth vein being well developed.

The remaining tribes of the Itonididinae may be separated from the Porricondylariae by the absence of a well-developed crossvein uniting subcosta and the third vein, though in a few forms this structure appears to be present. A little experience suffices to distinguish between this pseudo or rudimentary vein and the characteristic form of the crossvein in the preceding tribe.

Lasiopterariae

The tribe Lasiopterariae comprises a number of well-marked forms recognizable for the most part by the great reduction and approximation of costa, subcosta and the third vein (plate 2, figures 4, 7, 8). These three veins are heavily scaled and the abdomen clothed with dark brown and silvery white or bronze colored scales. The reduction of subcosta has proceeded to such an extent that it rarely extends beyond the middle of the wing and frequently reaches only the basal fourth while the third vein joins the anterior margin at a point between the basal and distal third, the place of union being usually marked by a snow-white, irregular spot, sharply defined by dark brown scales. The claws are almost invariably unidentate. The antennae are short in both sexes, the segments being sessile and cylindric, the length of the segment rarely being one half greater than its diameter. The number of segments varies from eleven to thirty-nine, frequently differing considerably between the sexes, there sometimes being a variation of four between male and female. The antennal segments are usually clothed with rather short, broad scales, having sparse subbasal and subapical whorls of slender, curved setae and low, broad circumfila near the base and subapically.

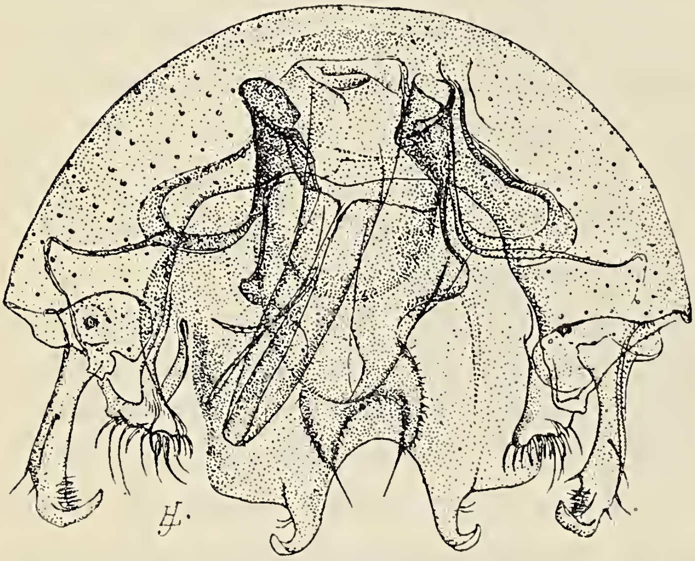

Figure 54 Epimyia carolina, male genitalia, illustrating the complexity of the structure in this genus (Author's illustration)

Lasioptera Meign. is the typical genus and may be easily recognized by the normal mouth parts and thorax, the usually quadriarticulate palpi, the closely fused third and fourth antennal segments, the well-developed pulvilli and the forked fifth vein. Kieffer has proposed the name Meunieriella for Lasioptera-like forms without the dorsal group of hooks (figure 39) on the ovipositor and if this division be accepted it would mean referring thereto a considerable number of American species now grouped under Lasioptera Meign. Prolasioptera Kieff. is distinguished from Lasioptera Meign. by the straight ventral plate, not emarginate posteriorly and the triarticulate palpi. Neolasioptera Felt is differentiated from Lasioptera Meign. by the four simple, long veins, that is the sixth is not partly fused with the fifth. The generalized Protaplonyx Felt has the third and fourth antennal segments at least separated by a distinct constriction, small or rudimentary pulvilli and simple claws.

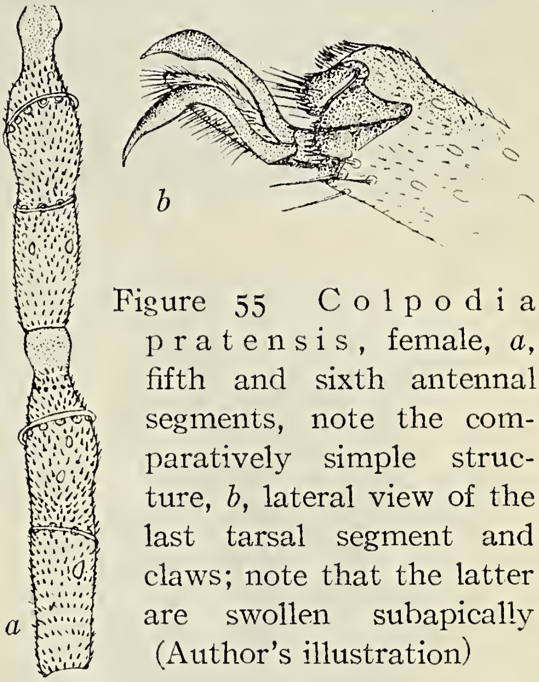

Figure 55 Colpodia pratensis, female, *a*, fifth and sixth antennal segments, note the comparatively simple structure, *b*, lateral view of the last tarsal segment and claws; note that the latter are swollen subapically (Author's illustration)

Another series of Lasioptera-like forms have the palpi biarticulate or uniarticulate. Asteromyia Felt is characteristic of this division and has peculiar food habits. Stefaniella Kieff. and Baccharomyia Tav. are distinguished by the third and fourth antennal segments not coalescing, the sometimes small or rudimentary pulvilli, the minutely-toothed or simple claws and the peculiar structure of the ovipositor.

There is a series of uniarticulate palpi and produced mouth parts represented by Baldratia Kieff., Baldratiella Kieff., and Baldratiola Kieff., the three being separable by structures found on the ovipositor. Another series has the mouth parts not produced and simple claws such as Aplonyx Perez, Dibaldratia Kieff., Stefaniola Kieff. and Salsomyia Tav., these likewise being most easily recognized by variations in the ovipositor.

All the preceding in the tribe have the thorax and mouth parts normal or nearly so and the two genera placed here are remarkable because of the great prolongation of these parts and the reduction in the number of antennal segments to thirteen or even ten. The more common of these is Clinorhyncha Loew, a genus easily distinguished by the three long veins, the fifth being forked and the other, possibly an invalid genus, is Ozirhynchus Rond. with its fifth vein simple.

The preceding genera in this tribe all have the Lasioptera facies. The three following are abnormal and easily recognized by the third vein being distinctly separated, usually strongly bowed and uniting with costa beyond the basal half (plate 2, figure 10). Camptoneuromyia Felt and Dialeria Tav. do not have the body thickly clothed with scales and are in some respects intermediate between the Lasiopterariae and the Dasyneuriariae, although the sessile antennal segments seem to place them in this tribe. The genus Trotteria Kieff. is more aberrant and may be easily recognized by the greatly produced first antennal segment (figure 3) with a length about 3 times its diameter and the thick clothing of silvery scales on the body. The antennae, except for the great prolongation of the first segment, are much like those of Lasioptera. The aciculate ovipositor is another peculiarity of Trotteria, although not unique in the group since there is a similar though not identical development in Aplonyx Perez.

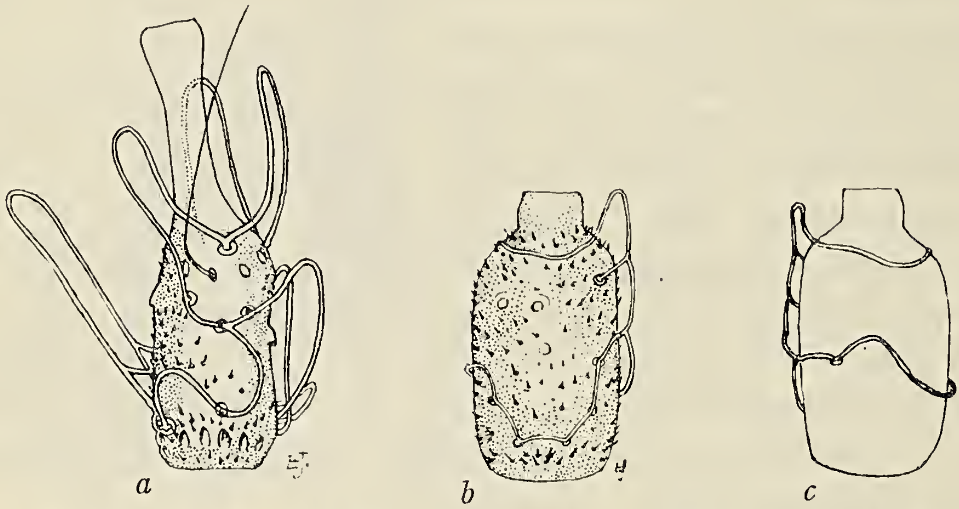

Figure 56 Lasiopteryx coryli, *a*, fifth antennal segment of male with the irregular and greatly produced circumfila; compare with similar structures of the female, *b*, *c* (Author's illustration)

Dasyneuriariae

The Dasyneuriariae are easily distinguished from the Lasiopterariae by the third vein being well separated from costa, the latter rarely thickly clothed with scales and the antennal segments usually with a length greater than their diameters and almost invariably stemmed. The claws are generally well developed and unidentate.

Rhabdophaga Westw. is one of the more generalized of the common genera in this tribe. The third vein is nearly straight (plate 2, figure 5) and unites with costa near or at the apex of the wing and the ovipositor is usually produced and not chitinized apically. The presence of a slightly chitinized trifid tooth on the claw separates the European Chortomyia Kieff. from Rhabdophaga Westw. and the chitinized bladelike tip of the ovipositor distinguishes Procystiphora Felt. A slightly curved third vein and a short ovipositor with orbicular lobes distinguishes Promikiola Kieff. from the preceding. The scaled costa is characteristic of a group of South American genera, Riveraella Kieff., Trichoperrisia Kieff., Xyloperrisia Kieff. and Pernettyella Kieff.

All of the preceding have the third vein uniting with costa at or near the apex of the wing, while the following show a distinctly higher degree of specialization in that the third vein joins the margin well beyond the apex of the wing, namely the African Baeomyza Kieff., the European Stomatosema Kieff. and the Asian Hallomyia Kieff.

The series of genera with quadriarticulate palpi are represented by a group in which the third vein unites with costa well before the apex of the wing. The most widely distributed and representative genus is Dasyneura Rond. with all the claws distinctly toothed, the wing veins not scaled and the membrane hyaline. Prowinnertzia Kieff. from the Seychelle islands is readily separated from Dasyneura by the simple fifth vein and the antennae with but one circumfilum below the middle of each segment. Others in this group have the wing vein distinctly scaled and the membrane more or less fuscous, notably Lasiopteryx Westw., Lauthia Kieff. and Cryptolauthia Kieff.

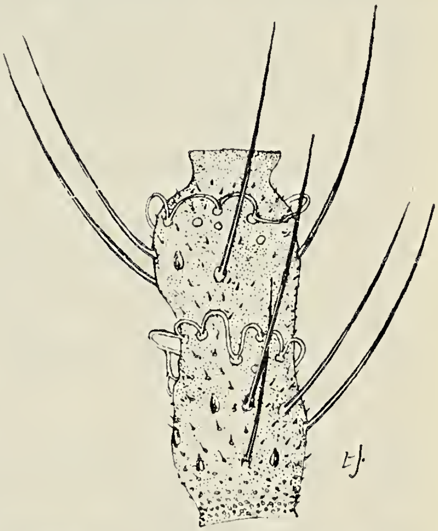

Figure 57 Dichrona gallarum, fifth antennal segment of female showing the development of setae and circumfila (Original)

All of the preceding in this tribe have fourteen or more antennal segments, while the following have from ten to twelve or thirteen, rarely fourteen segments. A moderately common and widely distributed genus typical of this division is found in Cystiphora Kieff. known to occur in both Europe and America and peculiar because of the spined ovipositor, a character which presumably separates it readily from the European Geocrypta Kieff. Antennal reduction has progressed still further in allied forms, there being but twelve segments in Macrolabis Kieff., Arnoldia Kieff., Harpomyia Felt and Neuromyia Felt.

A group of genera with reduced antennae is distinguished by the thorax and abdomen being plainly covered with scales, as Sphaerolauthia Kieff., and Ledomyia Kieff. with ten to twelve antennal segment. Coccomyza DelGuer. has twelve antennal segments in the female and fourteen in the male. Finally there is Brachyneuriella Kieff. with the anterior claws only toothed, the fifth vein simple and the ovipositor short.

Palpal reduction occurs in this tribe as elsewhere. The following series has triarticulate palpi: Dryomyia Kieff., Calopedila Kieff., Spartiomyia Kieff., Cystiphora Kieff. (discussed above), Allomyia Felt and Rhizomyia Kieff., all with unidentate, rarely bidentate claws. The remarkable Ctenodactylomyia Felt known from subtropical America and the Philippine islands is easily separated from the preceding by the pectinate claws.

There are two genera, namely, Diarthronomyia Felt, and Coccidomyia Felt in this tribe with biarticulate palpi. The former seems to have developed most successfully in the western United States, specially upon certain desert plants, while the latter appears to be predacious upon certain coccids.

Reduction in palpi is carried to the uniarticulate condition in a series comprising the American, Ficiomyia Felt with its forty-one antennal segments and subapical terminal clasp segment, the South American and presumably Asiatic, Scheueria Kieff. with its twenty antennal segments and unidentate claws, the South American Guarephila Tav. with its sixteen or eighteen antennal segments and trifid claws and lobed basal clasp segment, this latter modification not being distinct in the closely allied and possibly identical Navasiella Tav. This series also includes Calmonia Tav. easily separated from its allies by the twelve antennal segments.

Oligotrophiariae

Members of the tribe Oligotrophiariae are distinguished primarily from the Dasyneuriariae by the simple claws, a character not always decisive since certain species present intergradations. The division appears to be a very useful one, though Messrs. Rübsaamen and Kieffer, have placed these very similar genera in one group. The Oligotrophiariae, specially the American fauna, seem to present characters not easily defined, which warrant their continuance as a separate tribe. The group as a whole, indicated partly by the simple claws and also by the more general tendency toward palpal reduction, appears to be more specialized. The divisions in this tribe are very similar to those in the preceding.

The series with quadriarticulate palpi is distinctly shorter and is represented by fewer dominant species than in the Dasyneuriariae. Phytophaga Rond. with its third vein joining the margin at or near the apex of the wing and the fourteen antennal segments, is typical of this section. Phegomyia Kieff., Craneiobia Kieff. and Phegobia Kieff. show specialization in the larger number of antennal segments, there being sixteen to twenty and twenty-four in Mikiola.

The remainder of the series with quadriarticulate palpi have the third vein uniting with the margin well before the apex. It contains the well known European and American Janetiella Kieff.

The number of genera with triarticulate palpi is much less in this division than obtains in the Dasyneuriariae. Oligotrophus Latr. is a typical genus with its somewhat generalized Dasyneura characters aside from the simple claws. The peculiar Philippine Luzonomyia Felt is remarkable because of the subapical reduced terminal clasp segment. The American Sackenomyia Felt is easily recognized by the aciculate or cultriform ovipositor (figure 46), while the short, chitinized terminal plate of the ovipositor serves to distinguish the European Phlyctidobia Kieff. A series of genera, mostly European and with but few species, are associated with Oligotrophus Latr., namely, Mikomyia Kieff., Semudobia Kieff., Apiomyia Kieff., Blastomyia Kieff. and Iteomyia Kieff., and the South American Uleia Rübs. and Lyciomyia Kieff. and Jorg.

The series with biarticulate or uniarticulate palpi is considerably larger than in the Dasyneuriariae. Rhopalomyia Rübs. is a typical American genus with its stemmed flagellate antennal segments in both sexes and the greatly reduced palpi. It is preeminently a Solidago feeder. In addition there may be found Walshomyia Felt, Isosandalum Keiff., Guignonia Kieff., Arceuthomyia Kieff. and Misospatha Kieff., all derivatives or modifications. The specialized Sackenomyia Felt is easily distinguished by the cultriform or more or less aciculate chitinized ovipositor.

Asphondylariae

The tribe Asphondylariae comprises mostly large, heavy bodied insects readily distinguished from the preceding tribes by the third vein being well separated from costa (plate 3, figure 2), the simple claws, the elongate, cylindric, sessile flagellate antennal segments (figure 17) and the usually aciculate ovipositor (figure 41). There are two distinct lines of development in this group, namely, no or comparatively little reduction in the palpi and a high degree of specialization in the circumfila, together with a comparatively generalized ovipositor as in Cincticornia Felt, and a reduction in palpi, a moderate development of the circumfila and the aciculate ovipositor as in Asphondylia H. Lw, This division has the ovipositor exserted and bearing apically lobes or triangular plates, while the terminal clasp segment of the male is usually serrate apically. Cincticornia Felt, with its quadriarticulate palpi, apical terminal clasp segment, the fused third and fourth antennal segments and the usually fine reticulations of the male circumfila, is typical of this group. The closely related European Polystepha Kieff. has a subapical terminal clasp segment, the third and fourth antennal segments are not fused and the male circumfila are coarsely reticulate. Caryomyia Felt appears to belong here rather than with the Itonididinariae with which it was at first associated. The peculiar Xenhormomyia Felt is easily recognized by its narrow wings and numerous circumfila.

Reduction in the palpi occurs in the American Feltomyia Kieff., the Australian Eocincticornia Felt and the Asian Daphnephila Kieff., the first two with the terminal clasp segment of the male serrate apically, the circumfila of the male coarse in the first and extremely fine and numerous in the second. Feltomyia Kieff. shows in the slight reduction of the terminal antennal segments in the female and the palpus a line of specialization very evident in Asphondylia H. Lw., while its terminal clasp segment indicates an affinity with Cincticornia Felt and the peculiar circumfila suggests conditions found in Schizomyia Kieff. Eocincticornia Felt is a striking example of extreme specialization in circumfila and also in the subapical and greatly reduced terminal clasp segment. Daphnephila Kieff. differs from the others in the bidentate subapical terminal clasp segment and the conical ovipositor.

The extreme of palpal reduction in this group is seen in the South American Ozobia Tav. with its uniarticulate palpi. Stephomyia Tav. is closely related to this genus.

The larger and typical division of this tribe is characterized by a protractile, aciculate or nearly aciculate ovipositor, and the usually unidentate or bidentate terminal clasp segment of the male genitalia. The practically worldwide Schizomyia Kieff. belongs in the series with quadriarticulate palpi and flagellate antennal segments with long, whorled hairs and two strongly sinuous and anastomosing circumfila. The aciculate ovipositor without lamellae apically serves to distinguish the genus from the closely related Kiefferia Mik. Another series, the African Tetrasphondylia Kieff., Parasphondylia Kieff. and the West Indian Xenasphondylia Felt, all have flagellate antennal segments with short hairs, not whorled as in the preceding group, and in the first two the flagellate antennal segments are sessile. The last named may be recognized by the subsessile flagellate antennal segments, each with a stem about one-fourth the length of the basal enlargement and by the claws being distinctly shorter than the pulvilli.

Biarticulate or triarticulate, rarely uniarticulate palpi are characteristic of the next division. Asphondylia H. Lw., like Schizomyia Kieff., is worldwide in distribution and typical of the group. The terminal clasp segment is bidentate, the ovipositor has a distinct, lobed pouch basally (presumably modified terminal lobes) and the distal part is a highly specialized aciculate organ (a modified acicula). Eumarchalia DelGuer. is distinguished from Asphondylia H. Lw. by the absence of the dorsal pouch. The South American Bruggmanniella Tav. also falls here and may be easily recognized by the opake subcostal cell and the ovipositor with a globose striate basal enlargement.

The next division has the terminal clasp segment of the male pectinate and comprises the peculiar South American Proasphondylia Felt with its apical terminal clasp segment, subaciculate ovipositor and similarity in certain respects to the American Cincticornia Felt. The South American Bruggmannia Tav. has the terminal clasp segment of the male apical and the ovipositor probably as in Schizomyia. Oxasphondylia Felt suggests in the ovipositor relationship with Asphondylia H. Lw., although it is easily distinguished by the coarsely reticulate circumfila in the female. The European Acroectasis Rübs. is separated from the preceding by the third vein uniting with costa near the distal fourth, although the long, very irregular circumfila and the slender unidentate terminal clasp segment suggests affinities with the preceding forms.

The extreme of palpal reduction is found in the African Houardiella Kieff., Pumiliomyia Steff., the South American Zalepidota Rübs. and the Philippine Diceromyia Felt. The bidentate condition of the terminal clasp segment in the last two suggests a relationship to Asphondylia H Lw. Zalepidota Rübs. is easily recognized by the remarkable broad subcostal cell and the rudimentary vein spur at the base of subcosta, while Diceromyia Felt is noteworthy because of the greatly produced apical spurs or horns of the terminal clasp segment, each with a length greater than the diameter of the segment. Both of these genera have the terminal clasp segment apical, while in Houardiella Kieff. it is subapical and conical.

Itonididinariae

The tribe Itonididinariae is characterized by the antennal segments of the male usually being greatly produced, binodose and the circumfila generally occurring in whorls of long loops or bows. The palpi vary from quadriarticulate to uniarticulate, while the claws may be simple or toothed. There are two main divisions, namely the Bifila (figure 23) with two whorls of circumfila on each flagellate antennal segment and nearly equal basal and distal enlargements and the Trifila (figure 22) with three such whorls and distinctly unequal nodes, the larger usually distal and bearing two circumfila.

This tribe is one of the richest in genera, species and structural variations, there being repeated instances of development along parallel lines. The great multiplicity of forms (about half the known genera and approximately one-third of the known species falling in this division) has made it very difficult to work out a satisfactory classification.

Bifila

The subtribe Bifila characterized above is comparatively small and like the much larger Trifila presents a number of interesting modifications. The first group in this subtribe has the flagellate antennal segments of the male all binodose and the palpi quadriarticulate. Three closely related subtropical genera, namely Indodiplosis Felt, Erosomyia Felt and Mangodiplosis Tav. have the claws on all legs toothed and the wings with greatly produced and broadly rounded areas posteriorly. The allied subtropical genus Toxomyia Felt is distinguished from the preceding by the claws of the anterior legs only being toothed and the posterior wing areas not being produced.

The remaining genera of this subtribe with all the flagellate antennal segments of the male binodose, have the claws on all the legs simple. Contarinia Rond. is a typical genus in this group which may be recognized by the costa not being thickened basally or scaled and the third vein interrupting the margin and uniting therewith at the apex of the wing. This is a large genus containing many forms, some of which present a very characteristic appearance. Stictodiplosis Kieff. is distinguished from the preceding by spotted wings and Procontarinia Kieff. and Cec. by the triangular basal lobe on the basal clasp segment. Thecodiplosis Kieff. is a more extreme form, usually with longer stems on the flagellate antennal segments. It is separated from Contarinia Rond. by the third vein not interrupting the margin at its union with costa and the related Sitodiplosis

Kieff. is characterized by the linear ventral plate being much longer than the dorsal plate and emarginate. Two genera, Stephodiplosis Tav. and Syndiplosis Rübs., have the third vein uniting with the margin beyond the apex of the wing and differ in minor characteristics. The greatly produced posterior area of the male wing noted in Indodiplosis Felt appears also in Lobopteromyia Felt (plate 3, figure 6), a genus showing also a marked shortening of the stems of the male flagellate antennal segments. The related Streptodiplosis Felt is distinguished by the distinctly longer stems of the flagellate antennal segments and the strongly chitinized convolute harpes. The reverse of the broad wing is seen in the specialized European Thurauia Rubs. with a wing length at least 3 times its width and a greatly produced chitinized ovipositor. The long stems of the flagellate antennal segments and the short circumfila also indicate a peculiar type. Thorodiplosis Felt may be recognized by the short ovipositor with its fleshy lobes. Lowodiplosis Kieff. has costa thickened basally to form a spindle-shaped enlargement and an aciculate ovipositor There are two genera with the wing membrane scaled, Endaphis Kieff., a parasite of aphids and peculiar because of the dorsal tooth on the first antennal segment and Lasiodiplosis Kieff. with its spotted wings.

A portion of the genera with quadriarticulate palpi falling in this subtribe have all or only a part of the flagellate antennal segments binodose, the remainder being cylindrical. Among those having all the flagellate antennal segments of the male cylindrical is Holobremia Kieff., with its claws toothed and curved at almost right angles, while Geisenheyneria Rübs., Monodiplosis Rübs. and Stroblophila Kieff. have simple claws and may be separated from each other by variations in the dorsal and ventral plate and terminal clasp segment in particular. Genera with the terminal flagellate antennal segments cylindric are Halodiplosis Kieff., Ametrodiplosis Rübs., Cyrtodiplosis Kieff. and Anthodiplosis Kieff. The first with circumfila about half the length of the setae, the second having circumfila forming short bows and the last two with these structures rudimentary.

Bifila with triarticulate palpi are represented by Dentifibula Felt and Pectinodiplosis Felt, both with the basal clasp segment lobed apically, the former with the lobe long and narrowly triangular and the latter with the lobe broadly rounded and not greatly produced. Dentifibula Felt is a well-marked, peculiar form, probably zoophagus, while Pectinodiplosis Felt presumably has similar habits. Myricomyia Kieff., Zeuxidiplosis Kieff. and Stenodiplosis Reut. are three genera readily distinguished from the preceding by the basal clasp segment being without a process apically. The Philippine Kronodiplosis Felt has uniarticulate palpi and the dorsal and ventral plates both long and emarginate.

Trifila

The subtribe Trifila is distinguished from all other Itonididinariae by the three whorls of circumfila on the male flagellate antennal segments (figure 22), the loops or bows usually being greatly produced and having a length exceeding the diameter of the enlargement. There is further a striking irregularity as a rule in the enlargements, the distal one generally being distinctly more produced than the subglobular basal node. There are, as in the preceding subtribe and the other tribes, well-marked lines of specialization, particularly in the claws and the reduction in the number of palpal segments, both of which have been used to considerable advantage in classification.

The first series in the Trifila have the claws on all the legs toothed and the palpi quadriarticulate. This is a striking group easily recognized by the greatly produced setae and circumfila, there being one or more bows and setae with a length 5 to 10 times that of the enlargement and extending at approximately right angles to it. One division has three well-developed circumfila on each flagellate antennal segment and comprises Tribremia Kieff., Isobremia Kieff., Cryptobremia Kieff. and Aphidoletes Kieff., all with much in common. The last named at least is predacious upon plant lice or aphids.

Another division of this group has two well-developed, irregular circumfila, the basal circumfilum on the distal enlargement forming a low band or in other words remaining in the primitive condition so characteristic of these structures in many females. The series grouped here comprises Bremia Rond. (figure 24), Homobremia Kieff., Heterobremia Felt and Lepidobremia Kieff. Certain species of Bremia Rond. appear to live in decaying wood.

A larger number of genera are distinguished from the preceding by the nearly regular and what might be considered normal circumfila at least for this group.

The American Youngomyia Felt is easily recognized by the conspicuous basal lobe on the basal clasp segment (plate 8, figure 2), the trinodose or nearly trinodose antennae and large size. Several members of the genus breed in flower buds. The European Therodiplosis Kieff. is separated by the binodose flagellate antennal segments of the male and the fact that the terminal clasp segment is not greatly produced. The African Farquharsonia Collin has a low or rudimentary middle circumfilum, greatly produced mouth parts and a lobed basal clasp segment.

Another series has no lobe on the basal clasp segment and may be recognized by the claws being curved at nearly right angles, such as Plesiobremia Kieff., Cleodiplosis Felt, Dichodiplosis Rübs., Thomasia Rübs. and Collinia Kieff. A closely related series does not have the claws strongly curved basally, namely, Geodiplosis Kieff., Calodiplosis Tav., Resseliella Seitn. and Harmandia Kieff. The African and South American Lopesia Rübs. would fall in this series were it not for the well-developed crossvein which compels its reference to the Porricondylariae. Four other genera known only in the female are provisionally placed here, namely, Dicrodiplosis Kieff., Delphodiplosis Felt, Schizodiplosis Kieff. and Cacoplecus Kieff.

The series with all the claws toothed comprises, as in other groups, a number of genera with triarticulate palpi. Peridiplosis Felt is easily recognized by the distinctly lobed basal clasp segment, the moderately short circumfila and the slightly constricted basal portion of the flagellate antennal segments of the male. The remaining genera in this division do not have the basal clasp segment lobed and most have subcylindric antennal segments in the female, namely, Kalodiplosis Felt, Kamptodiplosis Felt and Heliodiplosis Felt. Roachadiplosis Tav. is peculiar on account of the two long circumfila and the rudimentary second suggesting conditions earlier noted in Bremia Rond. while the South American Epihormomyia Felt is peculiar because some of the flagellate antennal segments of the female are binodose.

Two genera, Allodiplosis Kieff. and Jorg. and Frauenfeldiella Rübs., fall in a group which has all the claws dentate and the palpi uniarticulate The first is noteworthy because of the well-developed crossvein nearly parallel with costa and the quadridentate claws, while the latter, possibly referable to the Asphondylariae, has bidentate claws and very conspicuous though low circumfila as in Asphondylia.

The second series in the Trifila have the claws on the anterior legs and sometimes those of the middle legs toothed, the claws on the posterior legs being simple. The first division in this series, species with quadriarticulate palpi, include a number of well-marked, somewhat related, yet nevertheless diverse genera. Phaenobremia Kieff., Rondaniella DelGuer. and Monobremia Kieff., have distinctly irregular circumfila, the first two with two and the last with one.

The remaining genera in this series have the circumfila regular or nearly so, four of these being easily separated by the conspicuous lobe on the basal clasp segment. This structure is apical and setose or spinose in Lobodiplosis Felt (plate 7, figure 2), subbasal and glabrous in Antichiridium Rübs. or basal, setose or nearly glabrous in Coquillettomyia Felt and Feltiella Rübs.

The remaining genera in this series have no distinct lobe on the basal clasp segment. The genus Karschomyia Felt (plate 7, figure 1) is easily separated from the others by the subfusiform terminal clasp segment and the strongly chitinized and very complex harpes. Three genera, namely, Clinodiplosis Kieff., Oribremia Kieff. and Profeltiella Kieff., have the claws curved nearly at right angles. The remaining three genera, Acaroletes Kieff., Mycodiplosis Rübs. and Camptodiplosis Kieff., have the claws only moderately curved, therefore not forming a right angle. Baeodiplosis Kieff. and Alethediplosis Tav., presumably fall here in the tabulation.

Here, as in preceding series, genera may be found with triarticulate palpi, namely, Diadiplosis Felt, Xiphodiplosis Felt and Chelobremia Kieff.

By far the largest series of the subtribe Trifila have the claws on all the legs simple and here, as elsewhere, we have groups with quadriarticulate, triarticulate, biarticulate and uniarticulate palpi, the first being by far the largest division.

The series with quadriarticulate palpi is conveniently divided by the position of the third vein, this uniting with the margin before the apex of the wing in Arthrocnodax Rübs., Microdiplosis Tav., Adelgimyza DelGuer., Cecidomyiella DelGuer., Silvestrina Kieff., Planodiplosis Kieff. and Chrysodiplosis Kieff. The last named is easily recognized by the densely brown haired, spotted wings, and is peculiar because of the finely denticulate hairs upon the flagellate antennal segments.

There is a small group of genera in this series with the third vein uniting with costa at the apex of the wing. Endopsylla Meij., Moreschiella DelGuer. and Doxodiplosis Kieff. have claws as long as the pulvilli. The remaining genera, namely, Plagiodiplosis Kieff. and Orthodiplosis Kieff., have claws plainly much longer than the pulvilli.

The large series of Trifila with simple claws have the third vein uniting with the margin well beyond the apex of the wing and, as in preceding groups, there are serveral genera with markedly irregular circumfila, namely Hadrobremia Kieff., Anabremia Kieff. and Plutodiplosis Kieff., the first two with hyaline wings and the last with yellow, black spotted wings and thickly scaled legs. The development of symmetrical circumfila and the migration of the third vein backward or forward along the wing margin must have proceeded simultaneously, and we are inclined to believe that from a taxonomic point, more stress can be laid upon the unusual modifications of the circumfila than upon variations in the position of the third vein.

Another division in this series is represented by genera with short circumfilar bows or with these structures apparently rudimentary. Most of these genera have hyaline wings and Prodiplosis Felt and Caryomyia Felt have at least some of the flagellate antennal segments cylindrical. The former is unusual since the basal flagellate antennal segments are typically binodose, while the tenth to the fourteenth are cylindric, stemmed and present characters practically as in the female, though the circumfila are very poorly developed or wanting. Caryomyia Felt with its low circumfila suggests strongly the condition obtaining in certain Asphondyliariae and is now considered as belonging to that tribe. The other genera falling here are Raodiplosis Felt and Macrodiplosis Kieff. Thorodiplosis Felt has the antennal stems as long or longer than the enlargement. Four other genera, known only in the female, are provisionally placed here, namely Ctenodiplosis Kieff., Eohormomyia Felt, Androdiplosis Felt and Diplecus Kieff.

The remainder of this series is represented by genera with well-developed circumfila, that is, the loops are mostly as long or longer than the diameter of the enlargement. One group of genera in this division has the claws bent at nearly right angles and three are easily recognized by the distinct lobe on the basal clasp segment, namely, Octodiplosis Giard, Trichodiplosis Kieff. and Charidiplosis Tav. In the other four, the basal clasp segment has no distinct lobe and here are placed Giardomyia Felt, Hyperdiplosis Felt, Mycetodiplosis Kieff. and Chaetodiplosis Kieff.

The remainder of the series have the claws only moderately bent, that is, there is no sharp curvature suggesting a right angle and here, we find a group with the basal clasp segment lobed. Four genera, namely, Epidiplosis Felt, Metadiplosis Felt, Coelodiplosis Kieff. and Tristephanus Kieff., all have the lobe apical: the first has a very long, curved, setose lobe, the second a triangular lobe, the third a small, densely haired lobe and the fourth a membraneous lobe extending from the basal clasp segment to the dorsal plate. Five genera, namely, Orseoliella Kieff., Isodiplosis Rübs., Lamprodiplosis Kieff., Lestodiplosis Kieff. and Coprodiplosis Kieff. have the lobe basal. Lestodiplosis Kieff. is a characteristic predaceous form with spotted wings.

The remainder of this series has the basal clasp segment without a conspicuous lobe. There are several species easily separated at the outset by striking features, namely, Xenodiplosis Felt, with trinodose flagellate antennal segments, the basal with two and the distal with one circumfilum; Eumerosema Kieff. with the anterior femora of the male plainly enlarged and the terminal clasp segment as long as the basal; Obolodiplosis Felt with trinodose flagellate antennal segments and a divided dorsal plate (plate 8, figure 1), the lobes being orbicular; Retinodiplosis Kieff., with its short, thick, flagellate antennal segments and transverse stems and rather heavy circumfila with numerous loops. The remainder of this series do not have the striking characters listed above and are most easily separable upon variations in the ventral plate. Parallelodiplosis Rübs., Blastodiplosis Kieff., Hypodiplosis Kieff., Brachydiplosis Rübs. and Eudiplosis Tav. fall here. The lobes may be linear and parallel as in Delodiplosis Tav. and Phyllodiplosis Kieff. In the final series composed of Paradiplosis Felt, Styracodiplosis Tav., Plesiodiplosis Kieff., Plemeliella Seitn., Pachydiplosis Kieff. and Itonida Meign., all have moderate sized genitalia. Four genera known only in the female, namely, Xylodiplosis Kieff., Lepidodiplosis Kieff., Chaetodiplosis Kieff. and Ouradiplosis Felt, are placed here. The anomalous Liebeliola Kieff. and Jorg. belongs here in the key if we disregard the well-developed crossvein which alone appears to warrant its reference to the Porricondylariae.

The series of Trifila with simple claws has another important division in the genera with triarticulate palpi and, as in the preceding major division, there is a group having circumfila with short bows or loops, the length of these latter being one-half the diameter of the enlargement or less and in one small series there is a distinct and remarkable characteristic extension of the mesonotum to such an extent as to practically conceal the head. This peculiar group comprises Hormomyia[1] H. Lw. (plate 3, figure 1), with twenty-three to thirty-six antennal segments in the male and fourteen in the female, the flagellate segments all binodose, and Trishormomyia Kieff. with but fourteen antennal segments in both sexes, the flagellate antennal segments of the female with three circumfila.

Another series with small circumfila does not have the thorax greatly produced over the head, contains three genera with the

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[1] Proshormomyia Kieff. grades so closely into Hormomyia H. Lw. that it appears best to sink it as a synonym.

basal clasp segment unarmed and the style not expanded apically. They are Pseudhormomyia Kieff., Dyodiplosis Rübs. and Caryomyia Felt (plate 3, figure 8). Massalongia Kieff. may be distinguished by the apical expansion of the style and its strongly chitinized sides. Two genera, Microplecus Kieff. and Holodiplosis Kieff., have a mesial spine on the basal clasp segment.

The remainder of this group with triarticulate palpi have the circumfila well developed, the loops with a length equal to the diameter of the enlargement or longer. Two genera, Ischnodiplosis Kieff. and Odontodiplosis Felt, have the basal clasp segment lobed. One of the most peculiar of these is the African Trisopsis Kieff. which is remarkable because of the division of the normal lateral eyes and the union of the meso-dorsal portions of each to form a trioptic combination. Other genera placed here, namely, Tricontarinia Kieff. and Atrichosema Kieff., have normal eyes and the claws a little longer than the pulvilli, while Hygrodiplosis Kieff. is distinguished by the claws being much shorter than the pulvilli.

The remainder of the genera having triarticulate palpi, well-developed circumfila and hyaline wings, are distinguished by the third vein uniting with the margin beyond the apex of the wing. These include Trissodiplosis Kieff., Acodiplosis Kieff., Taphodiplosis Kieff., Haplodiplosis Rübs., Centrodiplosis Kieff., Adiplosis Felt, Lowiola Kieff., Plecophorus Kieff. and Aplecus Kieff., the last two and Putoniella Kieff. being known only in the female. Two other genera, Stictobremia Kieff. and Ampeloscuta De Stef., have spotted wings.

The series of Trifila has a well-marked group of peculiar forms most easily recognized by the biarticulate palpi. Dichrona Rübs. (figures 8, 57) and Perodiplosis Kieff. have short or only moderately long circumfila. Dishormomyia Kieff. has the thorax produced over the head as in Hormomyia H. Lw.

The remainder of the group with biarticulate palpi have the circumfila long or at least moderately long and comprise a series of genera, namely Conodiplosis Kieff. and Jorg., Neurodiplosis Kieff., Orseolia Kieff. and Mass., Braueriella Kieff., Compsodiplosis Tav., Massalongia Kieff., Anadiplosis Tav., Jorgensenia Kieff., and Courteia Kieff. The African Scopodiplosis Felt has yellow wings conspicuously spotted with fuscous.

The proposed tribe, Anadiplosariae (Tavares, Broteria, Ser. Zool., 17:59, 1918) based largely upon characters found in the larvae and pupae of Anadiplosis Tav. should be discussed here. There is no question but that peculiar characters are presented by the immature stages. They are not in our estimation of sufficient importance to warrant any such major division and it is very doubtful if the group as characterized, could be fitted into the present classification or take a logical position in any system of the future. We question the wisdom of attempting to use larval structures for taxonomic purposes without a wide knowledge of the variations and their relationship to adult characters. The genus Rübsaamenodiplosis Tav. (Broteria, Ser. Zool. 17:61, 1918) erected on larval characteristics is presumably allied to Anadiplosis Tav.

The remaining Trifila having simple claws are distinguished by their uniarticulate palpi, and represent an extreme in specialization. The peculiar Dichrona Rübs. is also placed here because the palpi may be either biarticulate or uniarticulate. Four genera, Monarthropalpus Rübs., Onodiplosis Felt, Gnesiodiplosis Tav. and Horodiplosis Felt, have fourteen antennal segments and hyaline wings. Cystodiplosis Kieff. has but thirteen antennal segments. The tropical Astrodiplosis Felt is distinguished by the simple claws, uniarticulate palpi and by the black and yellow marked wings.

KEYS TO THE SUBFAMILIES, TRIBES AND GENERA OF THE ITONIDIDAE OF THE WORLD[1]

Key to Subfamilies and Tribes

a Metatarsus longer than the following segment; 5 tarsal segments; wings with at least 4 long veins; crossvein usually present.............. Subfamily Lestremiinae, p. 136

b Fourth vein forked....................Tribe Lestremiinariae, p. 136

bb Fourth vein simple.................Tribe Campylomyzariae, p. 136

aa Metatarsus longer or shorter than the following segment; wings with not more than 3 long veins; crossvein and circumfila wanting.............. Subfamily Heteropezinae, p. 138

aaa Metatarsus always shorter than the following segments; wings with 3 or 4 long veins; circumfila present......Subfamily Itonididinae, p. 139

b A distinct crossvein uniting the third vein and subcosta and usually parallel with costa.................Tribe Porricondylariae, p. 139

bb No distinct crossvein uniting the third vein with subcosta

c Costa thickly scaled; the third vein usually very close to the anterior margin of the wings; antennal segments sessile, cylindric, short, never produced...........Tribe Lasiopterariae, p. 142

cc Costa rarely thickly clothed with scales, the third vein well separated therefrom; antennal segments usually with a length greater than their diameter

d Flagellate antennal segments cylindric, never binodose in the male

e Claws toothed............Tribe Dasyneuriariae, p. 144

ee Claws simple

f Flagellate antennal segments cylindric or subcylindric, not greatly elongated, usually stalked in the male; ovipositor not aciculate............... Tribe Oligotrophiariae, p. 147

ff Flagellate antennal segments cylindric, elongate, sessile; ovipositor usually aciculate.............. Tribe Asphondylariae, p. 150

dd Flagellate antennal segments of the male greatly produced, binodose; circumfila usually forming long loops....... Tribe Itonididinariae, p. 153

e Nodes of the male flagellate antennal segments equal, only two circumfila.........Subtribe Bifila, p. 154

ee Nodes of the male flagellate antennal segments plainly unequal, three circumfila...Subtribe Trifila, p. 157

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[1] Revised from Phil. Jour. Sci. 13:296–324, 1918.

Lestremiinae

Lestremiinariae

Key to the Genera [1]

a Antennae at least moderately developed, with 11 to 16 segments, the second not greatly enlarged
  b Costa continuous and extending beyond the apex of the wing [2] (B. 165, p. 129)..Catocha Hal.
  bb Costa not attaining the apex of the wing, practically disappearing at its union with the third vein (B. 165, p. 133)....Lestremia Macq.
aa Antennae greatly reduced, only 8 to 10 or 11 segments
  b Second antennal segment greatly enlarged; flagellate segments very short
    c Subcosta and third vein distinctly united as though by a very short crossvein. The fork formed by the two branches of the fourth vein even (B. 165, p. 142)............Microcerata Felt
    cc Subcosta and third vein not fused and with no trace of a cross vein
      d Fork of the fourth vein with the two branches even (Ins. Insci. Men. 2:118).....................Konisomyia Felt
      dd Fork of the fourth vein with the branches irregular (B. 165, p. 148)...........................Tritozyga H. Lw.
  bb Second antennal segment normal
    c Flagellate segments not greatly reduced (B. 165, p. 150)........ Neptunimyia Felt
    cc Flagellate segments sessile, with a length only a little greater than the diameter (B. 165, p. 151)..............Neocatocha Felt

Campylomyzariae

Key to the genera [3]

a Wingless or, if wings are present, the fifth vein simple
  b Claws with long, parallel teeth, the pulvilli very short (B. 165, p. 155) ....Strobliella Kieff.
  bb Claws denticulate, the pulvilli absent (B. 165, p. 155)............... Wasmanniella Kieff.
  bbb Claws simple (Fasc. 152, p. 301)....................Pezomyia Kieff
aa Winged, fifth vein forked
  b Third vein usually well separated from costa and frequently uniting therewith at or beyond the apex
    c Flagellate antennal segments globose, stemmed in both sexes and ornamented only with whorls of long hairs
      d Fourth vein present
        e Palpi triarticulate or quadriarticulate
          f Wings normal, slender, antennal segments, male 14, female 11 (B. 165, p. 156).......Joannisia Kieff.

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[1] See N. Y. State Mus. Bul. 165, 1913, p. 129, for Key to American genera.

[2] References are to the more accessible or later generic accounts and are added to facilitate referring to earlier literature.
B. and Rep't refer to Bulletins and Reports respectively of the New York State Museum.
Fasc. 152 refers to Kieffer's monumental work in "Genera Insectorum."
Bib. Agr. Col. '18 is a condensation of Biblioteca Agraria Coloniale published at Florence by the Instituto Agricolo Coloniale Italiano, 1918.

[3] See N. Y. State Mus. Bul. 165, 1913, p. 154–55 for key to American genera.

ff Wings broad, not twice as long as wide, antennal segments, female 12 (B. 165, p. 160)............ Projoannisia Kieff.

ee Palpi biarticulate, the male with 14 and the female with 13 antennal segments, the claws strongly bent, dilated subapically (B. 165, p. 160)..........Peromyia Kieff.

dd Fourth vein wanting

e Antennal segments stemmed (B. 165, p. 161)........... Trichopteromyia Will.

ee Antennal segments sessile, the second enlarged, globose; palpi triarticulate (B. 165, p. 162)....Ceratomyia Felt

cc Flagellate antennal segments with the enlargement transverse and bearing a whorl of stemmed disks (Fasc. 152, p. 291)......... Xylopriona Kieff.

ccc Flagellate antennal segments cylindric, subsessile

d Male with 12, female with 9 antennal segments, fourth vein rudimentary, obsolete distally (B. 165, p. 161)............ Mycophila Felt

dd Female with 18 segments, the enlargements of the flagellate segments with a whorl of 4 awl-shaped appendages (Fasc. 152, p. 290).........................Tetraxyphus Kieff.

bb Third vein rarely extending to the apex of the wing; flagellate antennal segments subsessile in the female, ornamented with crenulate whorls or other structures more complex than irregular whorls of simple hairs

c Palpi triarticulate

d Wings wanting, reduced or normal; antennae with 14 or 15 segments, the enlargements with stemmed disks (Fasc. 152, p. 301)............................Pezomyia Kieff.

cc Palpi quadriarticulate, as a rule

d Antennae very short, the male with 10 to 11, the female with 6 to 8 subsessile segments, the second greatly enlarged (B. 165, p. 163)..........................Micromyia Rond.

dd Antennae not very short, the male with 14, the female with 11 to 22 antennal segments, the second not greatly enlarged (B. 165, p. 164)........Campylomyza Meign.[1]

e Flagellate antennal segments with a more or less distinct collar subapically, forming a more or less cup-shaped cavity

f Claws denticulate, the pulvilli well developed (B. 165, p. 172).........................Prionellus Kieff.

ff Claws arched, enlarged slightly subapically and with transverse striations; the pulvilli about half the length of the claws (Fasc. 152, p. 300).......... Prosaprionus Kieff.

fff Claws simple

g Pulvilli short or rudimentary (B. 165, p. 182).... Aprionus Kieff.

gg Pulvilli as long as the claws

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[1] This genus is insufficiently defined and as here limited is practically of supergeneric value

h Ovipositor large, covered with long hairs, with two divergent lobes and a small lobe basally (Fasc. 152, p. 293)........Urosema Kieff.

hh Ovipositor not as above, triarticulate. (Fasc. 152, p. 299)............Cylophora Kieff.

ee Flagellate antennal segments with a subapical whorl of stemmed disks

f Claws with a minute subapical tooth (B. 165, p. 183).. Monardia Kieff.

ff Claws simple, a little shorter than the pulvilli (Fasc. 152, p. 299).................Amblyspatha Kieff.

eee Flagellate antennal segments with reniform processes subapically, claws bent at right angles, dilated subapically (B. 165, p. 193)...............Bryomyia Kieff.

eeee Flagellate antennal segments with subapical whorls of short, stout, usually recurved spines (B. 165, p. 194).... Cordylomyia Felt

eeeee Flagellate antennal segments with series of whorls of short, stout, curved spines (B. 165, p. 200)................ Corinthomyia Felt

Heteropezinae

Key to the genera[1]

a Metatarsus longer than the second segment

b Tarsi quadriarticulate

c Three long veins

d Palpi quadriarticulate (in amber) (B. 165, p. 205)[2].......... Meunieria Kieff.

dd Palpi triarticulate (B. 165, p. 205)........................ Palaeospaniocera Meun.

ddd Palpi biarticulate (B. 165. p. 205)...........Miastor Mein.

dddd Palpi uniarticulate (Fasc. 152, p. 312)....................... Peromiastor Kieff.

cc One long vein, wings very narrow (B. 165, p. 209)............. Neostenoptera Meun.

bb Tarsi triarticulate, 2 long veins

c Antennal segments cylindric (B. 165, p. 209).................. Heteropeza Winn.[3]

cc Antennal segments globose (amber) (B. 165, p. 210)........... Monodicrana H. Lw [2]

aa Metatarsus shorter than the second segment

b Tarsi quinquearticulate

c Wing membrane finely haired

d Third vein extending to the apex of the wing

e Palpi quadriarticulate

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[1] See N. Y. State Mus. Bul. 165, 1913, p. 204, for key to American genera.

[2] Location provisional.

[3] Kunstler and Chaine Compt. Rend. Soc. Biol. (1902) 54, 535, give the characters of a form reared from bananas as follows: Tarsi biarticulate, the first segment longer than the second; wings with two or three long veins, the first two branched; palpi quadriarticulate. It was referred to the Heteropezinae though no name was proposed and is presumbaly related to Heteropeza Winn. and Monodicrana H. Lw.

f Fifth vein forked (B. 165, p. 210).................. Haplusia Karsch.

ff Fifth vein simple (B. 165, p. 211)................ Johnsonomyia Felt[1]

ee Palpi triarticulate, wings acuminate (B. 165, p. 214).... Meinertomyia Felt

eee Palpi uniarticulate, wings acute apically (B. 165, p. 215).. Leptosyna Kieff.

dd Third vein not extending to the apex of the wing

e Palpi biarticulate (B. 165, p. 216)......Frirenia Kieff.

ee Palpi triarticulate

f Fifth vein simple, claws simple, the male genitalia very complex (B. 165, p. 217)........Epimyia Felt

ff Fifth vein forked, claws unidentate, the male unknown (Bib. Agr. Col., '18, p. 56).Gioliella Del Guer.

cc Wing membrane scaled

d Fifth vein forked, palpi quadriarticulate (in amber) (B. 165, p. 217).........................Ledomyiella Meun.

dd Fifth vein simple

e Four simple long veins, palpi biarticulate, antennal segments stemmed in the female (B. 165, p. 218)....... Kronomyia Felt

ee Three simple long veins, palpi triarticulate (B. 165, p. 219) Brachyneura Rond. (Spaniocera Winn.)

bb Tarsi biarticulate (B. 165, p. 223)...................Oligarces Mein.

ITONIDIDINAE

Porricondylariae

Key to the genera[2]

a Crossvein not parallel with costa, forming a well-marked angle therewith

b Four long veins, the fifth simple, the sixth free

c Fifth vein arising from the third near the cross-vein, a supernumerary vein at the basal third of subcosta (Fasc. 152, p. 283).. Diallactes Kieff.

cc Fifth vein arising from the base of the wing, no supernumerary vein at the basal third of subcosta

d Fifth vein well developed; circumfila modified to form horseshoelike appendages on opposite faces of the segment (B. 180, p. 130).........Winnertzia Rond. (Syn. Winnertziola Kieff.)

dd Fifth vein rudimentary, obsolete basally and apically (Australian) (N. Y. Ent. Soc. J. 19:39)......Gonioclema Skuse[3]

ddd Fifth vein wanting, palpi biarticulate, circumfila as in Winnertzia (N. Y. Ent. Soc. J. 17:28).......Parwinnertzia Felt

bb Three long veins, the sixth a branch of the fifth or wanting

c Wings not very long and narrow, the crossvein at an oblique angle to costa

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[1] The Australian Necrophlebia Skuse and Chastomera Skuse are apparently closely related to this American genus and are provisionally associated therewith.

[2] See N. Y. State Mus. Bul. 180, 1915, p. 128–30 for key to American genera.

[3] Location provisional.

d Fifth vein forked, the sixth a branch of the fifth

e Fifth vein close to the posterior margin and uniting therewith near the basal half; palpi triarticulate; terminal clasp segment short (Fasc. 152, p. 262)...... Bryocrypta Kieff.

ee Fifth vein not close to the posterior margin, uniting therewith near the distal fourth

f No supernumerary vein at base of subcosta; palpi quadriarticulate; claws toothed; terminal clasp segment greatly produced, slender. (B. 180, p. 142.) Didactylomyia Felt

ff Supernumerary vein at base of subcosta, claws simple

g Palpi quadriarticulate, lobes of ovipositor elliptical (Fasc. 152, p. 251)....Liebeliola Kieff. & Jorg.

gg Palpi uniarticulate, ovipositor spined, the lobes triangular (Ent. News, 32:141). Alexomyia Felt

dd Fifth vein simple, the sixth wanting

e Palpi quadriarticulate (B. 165, p. 211)..Johnsonomyia Felt[1]

ee Palpi biarticulate (Fasc. 152, p. 261)..Colomyia Kieff.

cc Wings usually very long, narrow, the crossvein almost at right angles to costa

d Fifth vein forked, the sixth a branch of the fifth; terminal clasp segment short, swollen, the claws usually simple (B. 180, p. 145)................................Colpodia Winn.

dd Fifth vein simple, not reaching the wing margin (Fasc. 152, p. 268)................................Clinophaena Kieff.

ddd Fifth vein simple, the sixth wanting (fossil)................ Palaeocolpodia Meun.

aa Crossvein parallel or nearly so with costa and apparently a continuation of the third vein

b Four long veins, the fifth simple, the sixth free

c Fifth vein not obsolete basally

d Distal portion of the abdomen not recurved dorsally

e Pulvilli longer than the unidentate claws; 16 or more antennal segments; ovipositor biarticulate (B. 180, p. 157)..............................Asynapta H. Lw.

ee Pulvilli shorter than the simple claws; 14 antennal segments; ovipositor triarticulate (Fasc. 152, p. 281).... Clinorhytis Kieff.

dd Abdomen slender, the distal portion recurved dorsally; claws toothed, the lobes of the ovipositor biarticulate (Fasc. 152, p. 278)..............................Rübsaamenia Kieff.

cc Fifth vein obsolete basally; abdomen greatly produced, at least 3 times the length of the remainder of the body (Fasc. 152, p. 267). Dicerura Kieff.

bb Three long veins, the sixth a branch of the fifth or wanting

c Fifth vein forked

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[1] The absence of circumfila compels the reference of this genus to the Heteropezinae, though the superficial wing and antennal structures would place it here. It has therefore been included in the key simply to facilitate identification.

d Circumfila of the male not forming long loops or bows as in the Itonididinariae

e Palpi quadriarticulate

f Antennal segments of the male greatly produced, or at least with a distinct stem

g Abdomen not recurved dorsally

h Claws simple

i Pulvilli as long as or a little shorter than the claws

j Flagellate antennal segments of the male globose, elongated and constricted in the middle in the female (B. 180, p. 166). . . . . Porricondyla Rond[1]

jj Flagellate antennal segments elongated and subcylindrical in the two sexes (Fasc. 152, p. 273). . . . . Phaenepidosis Kieff.

ii Pulvilli rudimentary

j Flagellate antennal segments of the female with a stem one-half to three-fourths the length of the enlargement; lobes of ovipositor biarticulate (Fasc. 152, p. 276). . . Parepidosis Kieff.

jj Flagellate antennal segments of the female sessile; lobes of the ovipositor very small (Fasc. 152, p. 276). . . . . Misocosmus Kieff.

hh Claws toothed

i Pulvilli as long as the claws

j Terminal clasp segment as long as the basal clasp segment, capitate apically (Fasc. 152, p. 270). . . . . . Dicroneurus Kieff.

jj Terminal clasp segment ellipsoidal, shorter than the basal clasp segment (Fasc. 152, p. 274). . . . . . Synaptella Kieff.

ii Pulvilli reaching at most to the middle of the claws

j Third and fourth antennal segments fused (Fasc. 152, p. 275). . . . . Synarthrella Kieff.

jj Third and fourth antennal segments not fused; terminal clasp segment a little longer than its diameter, almost truncate, the margin spined (Fasc. 152, p. 275). . . . . Prosepidosis Kieff.

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[1] Cecidophila Rübs., type artemisiæ Rübs. (Rübs. '15*b*, p. 551) may fall here in the key.

iii Pulvilli rudimentary
  j Claws strongly curved, almost at right angles, the teeth equally long (Fasc. 152, p. 250)............. Tetradiplosis Kieff. & Jorg.
gg Abdomen slender, recurved dorsally (B. 180, p. 179).....................Camptomyia Kieff.
ff Antennal segments not greatly produced in both sexes
  g Basal clasp segment ovate, denticulate apically; terminal clasp segment wanting (B. 180, p. 189). Dirhiza H. Lw.
  gg Male genitalia presumably normal; flagellate antennal segments subsessile or nearly so; lobes of the ovipositor normal (Fasc. 152, p. 269).....................Prodirhiza Kieff.
ee Palpi triarticulate (Fasc. 152, p. 252)..Lopesiella Tav.
eee Palpi uniarticulate, penultimate abdominal segment of female swollen, open dorsally (Rubs. '15, p. 448)...... Machaeriobia Rübs.
dd Circumfila of the male forming long loops as in the Itonididinariae
  e Palpi quadriarticulate (Fasc. 152, p. 253)..Lopesia Rübs.
  ee Palpi uniarticulate (Fasc. 152, p. 254)................. Allodiplosis Kieff. & Jorg.
cc Fifth vein simple, the sixth wanting
  d Claws denticulate, as long as the pulvilli or at most twice as long as the pulvilli (B. 180, p. 188)..Holoneurus Kieff.
  dd Claws toothed, more than twice the length of the pulvilli. (Fasc. 152, p. 266)......................Coccopsis Meij.
bbb Five long veins, the fourth vein simple and partly obsolescent, the fifth and sixth veins free.
  c Palpi quadriarticulate, 16 antennal segments, the fifth with a stem 2½ times the length of the basal enlargement. (Ent. News, 30:220) Hormosomyia Felt

Lasiopterariae

Key to the genera[1]

a Third vein very near costa and uniting therewith at or before the basal half, very rarely near the distal third
  b Mouth parts and thorax normal, that is, not greatly prolonged
    c Palpi with three or four segments
      d Third and fourth antennal segments coalescent or closely fused; pulvilli always well developed
        e Three long veins, the fifth forked some distance from its base
          f Ventral plate bilobed; palpi usually quadriarticulate (B. 198, p. 107)..............Lasioptera Meig.[2] [3]

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[1] See N. Y. State Mus. Bul. 198, 1918, p. 102–103 for key to American genera.

[2] Kieffer has proposed the name Meunieriella for species of Lasioptera without the dorsal group of hooks on the ovipositor. This, if adopted, would mean placing a considerable number of American forms now referred to Lasioptera into this new genus.

[3] Dolicholabis Tav. near to and possibly identical with Lasioptera Meig., though Tavares separates it from Meunieriella Kieff. (Lasioptera Meig. in part) by the slender, greatly produced genitalia in particular.

ff Ventral plate straight, not emarginate; palpi triarticulate (Fasc. 152, p. 33)........Prolasioptera Kieff.[1]

ee Four simple long veins (B. 198, p. 171)................ Neolasioptera Felt[2]

dd Third and fourth antennal segments not coalescent, at least separated by a distinct constriction; pulvilli sometimes small or rudimentary

e Palpi quadriarticulate; claws simple (B. 198, p. 104)...... Protaplonyx Felt

cc Palpi biarticulate or uniarticulate

d Third and fourth antennal segments coalescent or closely fused; pulvill always well developed

e Palpi uniarticulate or biarticulate, rarely triarticulate (B. 198, p. 205)........................Asteromyia Felt[3]

dd Third and fourth antennal segments not coalescent, at least separated by a distinct constriction; pulvilli sometimes small or rudimentary

e Palpi biarticulate, claws toothed or simple; terminal lobe of the ovipositor rounded, dorsally with a chitinous barbed process (B. 198, p. 103).......Stefaniella Kieff.

ee Palpi biarticulate, claws simple, ovipositor moderately long, with two distinct setose lobes (Broteria, 15:129).. Baccharomyia Tav.

eee Palpi uniarticulate

f Mouth parts produced

g Claws distinctly toothed

h Ovipositor with a group of hooks on the basal half (B. 198, p. 104)......Baldratia Kieff.

hh Ovipositor without hooks but with produced chitinous pectinate appendages, lobes broad (Fasc. 152, p. 26).......Baldratiella Kieff.

gg A very small basal tooth on the claws; ovipositor stout, curved, the distal portion slender, almost aciculate (Fasc. 152, p. 24)...Baldratiola Kieff.

ff Mouth parts not produced, normal; claws simple

g Ovipositor aciculate (B. 198, p. 104).......... Aplonyx Perez.

gg Ovipositor with two diverging lobes (Fasc. 152, p. 23)....................Dibaldratia Kieff.

ggg Ovipositor obliquely truncate distally, with a row of hooks dorsally; head very small, well under the mesonotum (Fasc. 152, p. 27)...... Stefaniola Kieff.

gggg Ovipositor irregularly triangular, and with a series of short, curved and conical spines (Broteria, 16:17)...........Salsolomyia Tav.

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[1] Alycaulus Rübs., type A. mikaniae Rübs., (Rübs. '15*b*, p. 476) approaches this genus closely. Gastinella Del Guer. appears to be a synonym.

[2] Rübsaamen ('15*b*, p. 559-60) erects the genera Thomasiella, type eryngii Vall. and Hybolasioptera, type cerealis Lind. based upon differences which are of doubtful value. There is a question as to how far we should go in breaking up the Lasioptera complex.

[3] Geraldesia Tav. appears to be a synonym.

bb Mouth parts and thorax prolonged; antennal segments 10 to 13
  c Three long veins, the fifth forked (B. 198, p. 233)................ Clinorhyncha Loew.
  cc Four long veins, the fifth simple (Fasc. 152, p. 20).............. Ozirhynchus Rond.

aa Third vein distinctly separated from costa and uniting therewith beyond the basal half
  b First antennal segment normal; not strongly produced; third vein strongly arched, it and the body not thickly clothed with scales (B. 198, p. 237)..........................Camptoneuromyia Felt.
  bb First antennal segment normal, not strongly produced; third vein moderately arched and somewhat distant from costa, it and the body not thickly clothed with scales (Broteria, 16:78)....Dialeria Tav.
  bbb First antennal segment produced, with a length about three times its diameter; the third vein and the body thickly clothed with shining, frequently silvery scales, ovipositor aciculate. (B. 198, p. 245).... Trotteria Kieff

Dasyneuriariae

Key to the genera[1]

a Palpi quadriarticulate
  b Antennae usually with 14 or more segments
    c Third vein uniting with the margin well beyond the apex of the wing
      d Fifteen antennal segments; wings hyaline; the ovipositor short
        e Claws normal, not strongly bent (Fasc. 152, p. 106).... Baeomyza Kieff.
        ee Claws bent almost at right angles; pulvilli rudimentary. (Fasc. 152, p. 106)................Stomatosema Kieff.
      dd Thirteen antennal segments; wings spotted; pulvilli almost half the length of the claws (Fasc. 152, p. 156).......... Hallomyia Kieff.
    cc Third vein uniting with costa near or at the apex of the wing
      d Costa without scales
        e Antennae with 14 to more than 20 segments, usually with 18 or more
          f Third vein slightly curved, 19 antennal segments, the ovipositor short, the lobes orbicular (Fasc. 152, p. 105)....................Promikiola Kieff.
          ff Third vein nearly straight, the ovipositor usually produced
            g Ovipositor not chitinized apically
              h Claws plainly unidentate, the tooth heavily chitinized (B. 175, p. 81)................ Rhabdophaga Westw.
              hh Claws with a slightly chitinized trifid tooth. (Fasc. 152, p. 63)......Chortomyia Kieff.

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[1] See N. Y. State Mus. Bul. 175, 1915, p. 80–81 for key to American genera. Radulella Del Guer. erected on larval characters, may fall in this tribe.

gg Ovipositor chitinized apically, bladelike, the claws weakly toothed (B. 175, p. 212)........ Procystiphora Felt.

dd Costa scaled

e Antennae with 16 segments, claws shorter than the pulvilli, the ovipositor long. (Fasc. 152, p. 64)..Riveraella Kieff.

ee Antennae with 18 segments, claws longer than the pulvilli (Fasc. 152, p. 65)................Trichoperrisia Kieff.

eee Antennae with 21 cylindrical segments, the legs scaled, the claws shorter than the pulvilli (Fasc. 152, p. 68).... Xyloperrisia Kieff.

eeee Antennae with 22 ovoid segments in the male, cylindrical in the female, claws shorter than the pulvilli. (Fasc. 152, p. 69)........................Pernettyella Kieff.

ccc Third vein uniting with costa well before the apex of the wing, straight or curved anteriorly and tapering but little

d Claws of the anterior legs toothed, those of the mid and posterior legs simple

e Costa scaled, antennal segments 14, ovipositor short (Fasc. 152, p. 110)...............Phaenolauthia Kieff.

dd Claws on all legs toothed

e Wing veins distinctly scaled, the membrane more or less fuscous

f Body sparsely scaled, 14 cylindrical segments, the circumfila produced irregularly in certain males (B. 175, p. 189)...............Lasiopteryx Steph.

ff Body scaled

g Claws of anterior legs, at least, toothed, more than twice the length of the pulvilli; 14 cylindrical antennal segments; ovipositor short (Fasc. 152, p. 109).............Lauthia Kieff.

gg Claws of all the legs toothed, pulvilli rudimentary, ovipositor short (Fasc. 152, p. 111)........ Cryptolauthia Kieff.

ee Wing veins not distinctly scaled, the membrane hyaline

f Fifth vein forked, the female ovipositor long, sometimes longer than the body, circumfila not greatly produced (B. 175, p. 115)........................ Dasyneura Rond.[1] (Microperrisia Kieff.)

ff Fifth vein simple, antennae with 12 segments, the one circumfilum below the middle of the segment; pulvilli very small (Fasc. 152, p. 83).......... Prowinnertzia Kieff.

bb Antennae with 10 to 12 or 13, rarely with 14 segments

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[1] Rübsaamen (Rübs. '15 *b.* p. 488–491) has separated a number of genera from Dasyneura and its allies as follows: Caulomyia Rübs., type radicifica Rübs.; Taxomyia Rübs., type taxi Inch.; Giraudiella Rübs., type inclusa Rübs.; Poomyia Rübs., type secalina H. Lw.; Bayeria Rübs. (Rübs. '14, p. 97), type erysimi Rübs.; Helicomyia Rübs., type saliciperda Duf.; Mikiella Rübs., type beckiana Mik.; Jaapiella Rübs., type catariae; Sterrhaulus Rübs., type corneolus Rübs.; Kaltenbachiella Rübs., type strobi Wtz.; Gephyraulus Rübs., type raphanistri Kffr.; Wachtliella Rübs., type dalmatica Rübs. and Lathromyza Rübs., type schlechtendali Kffr. These are distinguished from each other and related genera by such minor differences that full descriptions and typical specimens would be necessary in many cases for determining their validity and position in a generic key.

c Thorax and abdomen plainly covered with scales; antennae with 10 to 12 segments

d All the claws toothed; ovipositor long

e Twelve subglobular antennal segments (Fasc. 152, p. 109) ....Sphaerolauthia Kieff.

ee Ten to 12 subcylindrical antennal segments; ovipositor greatly produced (Fasc. 152, p. 111).............. Ledomyia Kieff.

eee Female with 12 and male with 14 sessile, narrowly ovate antennal segments; dorsal plate divided, the lobes oval; ventral plate deeply and roundly emarginate, the clasp segments short, and relatively slender (Bib. Agr. Col., '18, p. 264)............................ Coccomyza Del Guer.

dd Claws of the anterior legs toothed, those of the mid and posterior legs simple, fifth vein simple, ovipositor short (Fasc. 152, p. 112)........................Brachyneurella Kieff.

cc Thorax and abdomen not plainly covered with scales

d Third vein uniting with costa near the apex of the wing

e Antennae with 13 or 14 segments; terminal clasp segment of the male short, swollen; ovipositor subglobose, spined apically (B. 175, p. 200)..........Cystiphora Kieff.

ee Antennae with 13 or 14 segments; claws as long as the pulvilli; terminal clasp segment large (Fasc. 152, p. 68) ....Geocrypta Kieff.

eee Antennae with 12 segments, the flagellate ones sessile in both sexes

f Terminal clasp segment large, greatly swollen (Fasc. 152, p. 65)....................Macrolabis Kieff.

ff Terminal clasp segment normal

g Harpes not sickle-shaped or greatly produced (B. 175, p. 196)..............Arnoldia Kieff.

gg Harpes sickle-shaped, greatly produced. (Can. Ent. 48:401)................Harpomyia Felt

dd Third vein uniting with costa well before the apex of the wint

e Antennae with 12 segments

f Third vein strongly curved, uniting with costa at the distal fourth; flagellate antennal segments of the male stemmed (B. 175, p. 197)....Neuromyia Felt

aa Palpi triarticulate

b Claws unidentate; rarely bidentate

c Antennae with 16 to 18 segments, the flagellate ones stemmed in the male, sessile in the female, claws shorter than the pulvilli; male genitalia not unusual (B. 175, p. 198)........Dryomyia Kieff.

cc Antennae with 18 segments, the flagellate one sessile, the claws with a length one-half that of the pulvilli, terminal clasp segment very large (Fasc. 152, p. 55)........ ....Calopedila Kieff.

ccc Antennal segments 15, costa haired, legs scaled, ovipositor long (Fasc. 152, p. 57)..........................Spartiomyia Kieff.

cccc Antennae with 13 to 14 segments

d Ovipositor short, subglobose, spined apically; terminal clasp segment of the male short, swollen (B. 175, p. 200)....... Cystiphora Kieff.

dd Ovipositor short, without an apical spine, pulvilli greatly produced and with a length nearly three times that of the claws (Econ. Ent. J. 11:380)..............Allomyia Felt[1]

cccc Antennae with 12 segments, terminal clasp segment slender, the dorsal and ventral plates deeply emarginate (B. 175, p. 202)... Rhizomyia Kieff.

bb Claws pectinate

c Antennae with 14 segments, the terminal clasp segment long, stout; the ovipositor short, the lobes broadly oval (U. S. N. M. 48:199)..............................Ctenodactylomyia Felt

aaa Palpi biarticulate

b Ovipositor aciculate as in Cystiphora (Rubs. '14, p. 94)............ Laubertia Rübs.

bb Ovipositor not aciculate.

c Antennal segments 14 to 18, the flagellate ones usually stemmed in both sexes (B. 175, p. 208)..............Diarthronomyia Felt (Dichetonyx Rübs., type foliorum H. Lw., Rübs., '14, p. 94)

cc Antennal segments 12, the flagellate ones in the male stemmed (B. 175, p. 210)............................Coccidomyia Felt

aaaa Palpi uniarticulate

b Antennal segments over 30, the flagellate ones stemmed in both sexes; the circumfila not reticulate or only slightly so, the unidentate claws longer than the pulvilli; the terminal clasp segment subapical ('22 Fla. Ent. p. 5–6, sum. No.)....................Ficiomyia Felt

bb Antennal segments 26, stemmed in the female; circumfila simple (Rübs. '15 *a*, p. 471)........................Haplopalpus Rübs.

bbb Antennal segments 20, the flagellate ones stemmed in the male, sessile in the female, circumfila reticulate, the unidentate claws shorter than the pulvilli (Fasc. 152, p. 38).....................Scheueria Kieff.

bbbb Antennal segments 16 in the male, 18 in the female, the flagellate ones in the male stemmed, the trifid claws longer than the pulvilli

c Basal clasp segment lobed, fifth vein forked (Broteria 8:18).... Guarephila Tav.

cc Basal clasp segment without a distinct lobe, fifth vein obsolescent distally (Broteria 17:93)...................Navasiella Tav.[2]

bbbbb Antennal segments 14 in male (Rübs., Marcellia 14:99)........... Amerhapha Rübs.

bbbbbb Antennal segments 12, stemmed in the male, sessile in the female, claws unidentate, wings broad, the third vein rather near costa (Broteria 15:173)...........................Calmonia Tav.

Oligotrophiariae

Key to the genera[3]

a Palpi quadriarticulate

b Third vein uniting with the margin well before the apex

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[1] Preoccupied by Allomyia Banks '16, Alassomyia n. nom. is hereby proposed.

[2] This may prove to be a synonym of Guarephila Tav.

[3] See N. Y. State Mus. Bul. 180, 1916, p. 195–96 for key to American genera.

c Antennae with 10 segments in the male, 9 in the female, claws very slender, curved almost at right angles; pulvilli rudimentary (Fasc. 152, p. 41)........................Properrisia Kieff.

cc Antennae with 14 or more segments

d Terminal clasp segment moderately large, pubescent, gradually tapering; ovipositor long, cylindric (B. 180, p. 217).. Janetiella Kieff.

dd Terminal clasp segment large, elongate-ellipsoidal, the dorsal and ventral plates bilobed; ovipositor protractile (Fasc. 152 p. 59)............................Zygiobia Kieff.

ccc Antennae with 13 segments

d Female having the stems of the flagellate segments with a length two-thirds that of the segments, the terminal clasp segment slender (Fasc. 152, p. 110)...Nanolauthia Kieff.

bb Third vein uniting with the margin at or very near the apex

c Antennae with 14 segments, the genitalia and ovipositor about as in Dasyneura (B. 180, p. 196).........Phytophaga Rond.[1]

cc Antennae with 16 to 20 segments

d Third and fourth antennal segments not fused

e Antennal segments in the male with a stem about two-thirds of the length of the segment; terminal clasp segment rather slender, long, tapering gradually (Fasc. 152, p. 56)..................................... Phegomyia Kieff.

ee Stems of the flagellate antennal segments as long as the basal enlargement, otherwise as in the preceding (Fasc. 152, p. 60)..................Craneiobia Kieff.

eee Stems of the flagellate antennal segments longer than the basal enlargement (Rubs. '15 *b*, p. 551)............ Cecidophila Rübs.

dd Third and fourth antennal segments fused, antennae with 18 or 19 segments, the stems of the flagellate segments with a length of one-half to two-thirds that of the segment; terminal clasp segment slightly enlarged, gradually tapering, the dorsal and ventral plates deeply bilobed (Fasc. 152, p. 61)................................Phegobia Kieff.

ccc Antennae with 20 to 24 segments

d Antennal segments of male stemmed, those of female sessile; dorsal and ventral plates emarginate, ovipositor short, lobed (Fasc. 152, p. 103)................Mikiola Kieff.

aa Palpi triarticulate

b Ovipositor distinctly chitinized

c Ovipositor aciculate or cultriform; antennal segments 12 to 24 (B. 180, p. 279)...........................Sackenomyia Felt.

cc Ovipositor short, with a rounded, chitinized terminal plate; antennal segments 13 (Fasc. 152, p. 51)............Phlyctidobia Kieff.

bb Ovipositor not chitinized

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[1] Caulomyia Rûbs., type radicifica Rübs. (Rübs. '15 *b*, p. 558), is erected on what appears to be insufficient grounds.

c Terminal clasp segment of male subapical, the basal clasp segment with a broad, apical lobe (Phil. J. Sci. 13:282)..............
Luzonomyia Felt

cc Terminal clasp segment of male apical

d Ovipositor almost truncate, apically without a distinct pocket; terminal clasp segment not large, the empodium twice as long as the claws, the third and fourth antennal segments not fused (B. 180, p. 226)................
Oligotrophus Latr.[1]

ccc Ovipositor with the terminal segment pocket-shaped, the empodium much longer or only a little longer than the claws

d Intermediate whorl of the flagellate antennal segments in the male with two greatly produced hairs, the third and fourth antennal segments fused, terminal clasp segment very large, elongate, ellipsoidal (Fasc. 152, p. 51)..Mikomyia Kieff.

dd Whorls of the flagellate antennal segments otherwise

e Basal clasp segment with a median, membranous, transparent prolongation attaining the tip of the ventral plate; terminal clasp segment large, pointed, ovoid

f Ventral plate deeply bilobed, third and fourth antennal segments fused in the male, the enlargement of the third a little longer than that of the fourth (Fasc. 152, p. 52)......Semudobia Kieff.

ff Ventral plate entire, third and fourth segments not fused, the enlargement of the third twice as long as that of the fourth (Fasc. 152, p. 53)...........
Apiomyia Kieff.

ee Basal clasp segment otherwise

f Stems of the flagellate antennal segments short in both sexes

g Antennae with 22 to 25 segments (palpi are given as biarticulate or triarticulate); costa, subcosta, and third vein scaled (Fasc. 152, p. 53)
Uleia Rübs.

gg Antennae with 17 segments, the flagellate segments with 5 or 6 slightly looped circumfila; wings with a supernumerary vein (Fasc. 152, p. 38)..............Lyciomyia Kieff. & Jorg.

ff Stems in the flagellate antennal segments long in the male, very short or wanting in the female

g Third and fourth antennal segments not fused; terminal clasp segment not large, gradually constricted, the larva with a breastbone (Fasc. 152, p. 54)..........Blastomyia Kieff.

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[1] Rubsaamen (Rübs. '15 *b*, p. 492) separates from this genus and its allies Boucheella Rübs., type artemisiae Bouche'; Didymomyia Rübs., type reaumuriana F. Lw.; Physemocecis Rübs., type ulmi Rübs. (Rübs., '14, p. 88); Pemphigocecis Rübs., type ventricola Rubs.; Hartigiola Rübs., type annulipes Hartig and Rondaniella Rübs., type bursaria Bremi. The characters used require full descriptions and sometimes typical specimens for the determination of their validity and position in a generic key.

gg Third and fourth antennal segments not fused; terminal clasp segment very large, swollen, the larva without a breastbone (Fasc. 152, p. 55) ......Iteomyia Kieff.

aaa Palpi biarticulate or uniarticulate
  b Ovipositor chitinized, cultriform or more or less aciculate (B. 180, p. 279)....................................Sackenomyia Felt
  bb Ovipositor not distinctly chitinized
    c Pulvilli nearly twice as long as the empodium
      d Palpi biarticulate (Fasc. 152, p. 39).....Psectrosema Kieff.
      dd Palpi uniarticulate (B. 180, p. 285).....Walshomyia Felt
    cc Pulvilli equal to the empodium; palpi uniarticulate (Fasc. 152, p. 40)..................................Isosandalum Kieff.
    ccc Pulvilli distinctly shorter than the empodium
      d Empodium as long as or longer than the claws
        e Third flagellate antennal segment of the male large and with three circumfila, the other segments with two whorls (Fasc. 152, p. 42)..........Guignonia Kieff.
        ee Third flagellate antennal segment not large and heavy and having no more circumfila than the others
          f Terminal clasp segment large, swollen, or only slightly constricted distally; ovipositor subcylindric, greatly protracted; terminal segment strongly constricted, pocket-shaped
            g Flagellate antennal segments with a long stem in both sexes; circumfila reticulate (B. 180, p. 230)................Rhopalomyia Rübs.[1]
            gg Flagellate antennal segments sessile or subsessile in the female, circumfila not reticulate
              h Empodium twice as long as the claws (Fasc. 152, p. 47)....Arceuthomyia Kieff.
              hh Empodium not longer or only a little longer than the claws; palpi uniarticulate; larva without a breastbone (Fasc. 152, p. 44) ....Misospatha Kieff.[2]

Asphondylariae

Key to the genera [3]

a Ovipositor protractile, aciculate or nearly so, the terminal clasp segment of the male usually unidentate or bidentate.
  b Palpi quadriarticulate
    c Flagellate antennal segments with long, whorled hairs and two very tortuous, anastomosing circumfila, expecially in the male

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[1] Rübsaamen (Rübs. '15 b, p. 491), has separated the following genera in this group, namely Bremiola Rübs., type onobrychidis Bremi and Schmidtiella Rübs., type gemmarum Rübs. (Rübs. '14, p. 89). The characters used are such that full descriptions and in some cases typical specimens would be necessary in order to determine their validity and correctly place the forms in a generic key.

[2] Panteliola Kieff. according to Kieffer is separated from Misospatha by the biarticulate palpi.

[3] Revised from Proc. U. S. Nat. Mus., 48:197–98, (1915); see N. Y. State Mus. Bul. 186, 1916, p. 102 for key to American genera.

d Terminal antennal segments of female greatly shortened

e Terminal clasp segment unidentate

f Ovipositor aciculate, without lamellae apically; larval breastbone bidentate (B. 186, p. 102).... Schizomyia Kieff.

ff Ovipositor subaciculate, with two very small lamellae apically; larval breastbone unidentate (Fasc. 152, p. 89)..........................Kiefferia Mik.[1]

dd Terminal antennal segments of female not greatly shortened.

e Terminal clasp segment pectinate (Rübs. '15, p. 435) Macroporpa Rübs.

ee Terminal clasp segment bidentate

f Pulvilli nearly as long as the claws; ovipositor of female unknown (Rubs. '15, p. 432)............ Gisonobasis Rübs.[2]

cc Flagellate antennal segments with short hairs, not whorled

d Flagellate antennal segments sessile without an appreciable stem

e Claws much longer than the pulvilli; the basal segment of the ovipositor with rows of minute spinules (Fasc 152, p. 95)..................Tetrasphondylia Kieff

ee Claws as long as the pulvilli; the first segment of the ovipositor finely striate, without spinules (Fasc. 152, p. 95).......................Parasphondylia Kieff.[3]

dd Flagellate antennal segments subsessile, with a stem about one-fourth the length of the basal enlargement; claws shorter than the pulvilli (U. S. N. M. P. 48:202)......... Xenasphondylia Felt

bb Palpi biarticulate or triarticulate, rarely uniarticulate

c Third vein uniting with the margin near the apex of the wing

d Circumfila in the female consisting of two comparatively simple bands

e Terminal clasp segments of the male unidentate or bidentate, not pectinate

f Subcostal cell normal, not opaque

g Ovipositor with a lobed proximal pouch not vesiculate basally; circumfila in the male very tortuous (B. 186, p. 114)..Asphondylia H. Lw.[4] (Syn. Monasphondylia Kieff.).

gg Ovipositor longitudinally striate, apparently without a lobed, proximal pouch, the circumfila of the male forming eight or nine moderately high transverse bands much as in Cincticornia (Bib. Agr. Col. '18, p. 120)..... Eumarchalia Del Guer.

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[1] Placochela Rübs. (Rübs. '16, p. 12), type nigripes Fr. Lw. is separated from this genus by the occurrence of but two circumfila united with one or two long fila instead of a netlike arrangement.

[2] Location provisional owing to the incomplete characterization of the genus.

[3] Metasphondylia Tav. is distinguished from Parasphondylia Kieff. by the more serpentine circumfila, specially the short longitudinal filum as compared with Asphondylia. The relatively high and sinuous circumfila suggests a relationship to Schizomyia.

[4] Ischnonyx Rübs. (Rübs. '16, p. 5), type verbasci Vall., is separated from Asphondylia by the slender uniformly bent claws, the American diervillae Felt also being referred to this genus. There is a question as to the validity of this distinction.

ff Subcostal cell opaque, the ovipositor with a globose, striate basal elargement (Fasc. 152, p. 99).... Bruggmanniella Tav.

ee Terminal clasp segment of the male pectinate

f Terminal clasp segment apical; ovipositor subaciculate, with submedian groups of hairs on the distal segment (U. S. N. M. P. 48:203).......... Proasphondylia Felt

ff Terminal clasp segment of the male subapical, the ovipositor probably as in Schizomyia (Fasc. 152, p. 98)......................Bruggmannia Tav.

dd Circumfila in the female forming five irregular, anastomosing bands; ovipositor as in Asphondylia (U. S. N. M. P. 48:204) ....Oxasphondylia Felt

cc Third vein uniting with costa near the distal fourth

d Palpi triarticulate; the circumfila low, very irregular; terminal clasp segment slender, unidentate; dorsal and ventral plates deeply emarginate (Fasc. 152, p. 113)........ .... Acroectasis Rübs.

bb Palpi uniarticulate

c Terminal clasp segment of the male subapical, conical (Fasc. 152, p. 96)...............................Houardiella Kieff.

cc Terminal clasp segment of the male bidentate

d Subcostal cell remarkably broad, a rudimentary vein spur at the base of subcosta (Fasc. 152, p. 98)....Zalepidota Rübs.

dd Subcostal cell not remarkably broad, no rudimentary vein spur at the base of subcosta; terminal clasp segment with greatly produced, tapering spurs or horns (Phil. J. Sci. 13: 283)................................Diceromyia Felt

ddd Terminal clasp segment strongly curved to a hook; antennae of the female with 14 and of the male 13 segments, the latter stemmed (Marcellia 16:75)............Pumilomyia Stef.

aa Ovipositor exserted, apically with lobes or triangular plates; terminal clasp segment of the male usually serrate apically

b Palpi quadriarticulate

c Terminal clasp segment of the male subapical; third and fourth antennal segments not fused, the circumfila coarsely reticulate in the male, the pulvilli longer than the claws (Fasc. 152, p. 90) ....Polystepha Kieff.

cc Terminal clasp segment of the male apical

d Flagellate antennal segments cylindrical, not strongly constricted; the circumfila usually with many fine reticulations in the male, the pulvilli usually shorter than the claws (B. 186, p. 150)......................Cincticornia Felt

dd Flagellate antennal segments cylindrical, sometimes rather strongly constricted, the circumfila forming transverse series of low lines or loops

e Wings relatively short, broad, three low circumfila, lobes of the ovipositor subtriangular (34th Rep't, p. 94).... Caryomyia Felt *ee* Wings long, narrow, ten or more circumfila with short loops in the male, lobes of the ovipositor narrowly oval (Natal Mus. Ann. 4:491).........Xenhormomyia Felt

bb Palpi triarticulate

c Terminal clasp segment of the male serrate apically

d Circumfila of male coarse, very irregular, four or five transverse fila to a segment, the plates of the ovipositor triangular (B. 186, p. 171).......................Feltomyia Kieff.[1]

dd Circumfila of male fine, about 18 transverse fila to a segment, the termimal lobes of the ovipositor roundly quadrate. (U. S. N M. P. 48:206)..............Eocincticornia Felt

cc Terminal clasp segment of the male bidentate, subapical, the ovipositor conical (Fasc. 152, p. 96)...........Daphnephila Kieff.

bbb Palpi uniarticulate; flagellate antennal segments subsessile, abdomen with caducous scales, the short ovipositor biarticulate

c Flagellate antennal segments of the female subsessile, twelfth to the fourteenth progressively shorter, the last conical (Fasc. 152, p. 97)......................................Ozobia Kieff.

cc Flagellate antennal segments of the female not reduced, except that the fourteenth is somewhat shorter (Broteria 14:54).......... Stephomyia Tav

Itonididinariae

Skeleton key to the genera

Bifila

- *a* Palpi quadriarticulate (p. 154)
  - *b* Flagellate antennal segments of the male all binodose (p. 154)
  - *bb* Some of the flagellate antennal segments of the male cylindrical (p. 156)
- *aa* Palpi triarticulate (p. 157)
- *aaa* Palpi uniarticulate (p. 157)

Trifila

- *a* Claws toothed on all the legs (p. 157)
  - *b* Palpi quadriarticulate (p. 157)
  - *bb* Palpi triarticulate, uniarticulate (p. 160)
- *aa* Claws on the anterior legs (and sometimes middle legs) toothed (p. 161)
  - *b* Palpi quadriarticulate (p. 161)
    - *c* Circumfila greatly produced (p. 161)
    - *cc* Circumfila regular (p. 161)
  - *bb* Palpi triarticulate (p. 162)
- *aaa* Claws all simple (p. 163)
  - *b* Palpi quadriarticulate (p. 163)
    - *c* Third vein before the apex of the wing (p. 163)
    - *cc* Third vein at the apex of the wing (p. 163)
    - *ccc* Third vein beyond the apex of the wing (p. 164)
      - *d* Circumfila irregular (p. 164)

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[1] Judging from larval characters, this genus is closely related to and may possibly be a synonym of Uleella Rübsaamen.

dd Circumfila with short bows or wanting (p. 164)
ddd Circumfila regular, with long loops (p. 165)
bb Palpi triarticulate (p. 170)
bbb Palpi biarticulate (p. 173)
bbbb Palpi uniarticulate (p. 174)

Key to the genera[1]

Bifila

a Palpi quadriarticulate
  b Flagellate antennal segments of the male all binodose
    c Claws on all legs toothed
      d Wings with greatly produced and broadly rounded areas posteriorly
        e Internal basal lobe of the basal clasp segment setose, the dorsal and ventral plates deeply emarginate, the lobes of the ventral plate very long, moderately narrow, the ovipositor very short, turned dorsally and not protractile (Can. Ent. 48:403)........Indodiplosis Felt
        ee Internal basal lobe of the basal clasp segment smooth, the dorsal and ventral plates broadly and slightly emarginate, the ovipositor with a length one-half that of the abdomen, protractile (B. 202, p. 81)..Erosomyia Felt
        eee Internal basal lobe of the basal clasp segment rudimentary, smooth; dorsal plate truncate, ventral plate broadly and roundly emarginate, ovipositor moderately long (Broteria 16:47)............Mangodiplosis Tav.
    cc Claws of anterior legs toothed
      d Wings normal, the posterior areas not greatly produced, the fifth antennal segment having the basal stem with a length about 2½ times its diameter (B. 202, p. 82)..............
Toxomyia Felt
    ccc Claws all simple
      d Costa thickened basally to form a spindle-shaped enlargement
        e All of the flagellate antennal segments of the male binodose and with circumfila; ovipositor aciculate (Fasc. 152, p. 142)....................Löwodiplosis Kieff.
      dd Costa not thickened basally
        e Wings of the male with the posterior area greatly produced and broadly rounded
          f Stems of the flagellate antennal segments of the male short, with a length about one-half the diameter, the harpes not strongly chitinized (B. 202, p. 84)..
Lobopteromyia Felt[2]
          ff Stems of the flagellate antennal segments of the male with a length over twice their diameter, the harpes strongly chitinized and convolute (Can. Ent. 48:405)....................Streptodiplosis Felt
        ee Wings narrow, with a length at least three times the width

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[1] See N. Y. State Mus. Bul. 202, 1918, p. 76–81 for key to American genera.

[2] Megaulus Rübs. (Rübs. '15 b. p. 461), type sterculiae Rübs., appears to be closely related to this American genus.

f The ovipositor greatly produced, chitinized (Fasc. 152, p. 175)..................Thurauia Rübs.

ff Ovipositor short, the lobes fleshy (Treubia 2:89)... Thorodiplosis Felt

cee Wings normal, neither specially broadened nor narrowed

f Costa thickly clothed with scales, the third vein uniting with the margin before the apex of the wing.

g The first antennal segment with a dorsal tooth, the wing membrane with narrow scales (Fasc. 152, p. 171)..........Endaphis Kieff.

gg The first antennal segment not toothed, the mesonotum with two lines of golden scales, the wings with smoky spots, iridescent (Fasc. 152, p. 146).............Lasiodiplosis Kieff.

ff Costa not scaled

g Third vein uniting with the margin at the apex of the wing

h Third vein interrupting the margin

i Basal clasp segment not lobed

j Ventral plate deeply bilobed

k Ovipositor long, slender; wings hyaline (B. 202, p. 93).... Contarinia Rond.[1]

kk As in Contarinia except that the wings are spotted (Fasc. 152, p. 183)............... Stictodiplosis Kieff

jj Ventral plate broad, very broadly emarginate (Rübs. '15 a, p. 461). Sphaerodiplosis Rübs.

ii Basal clasp segment with a triangular lobe basally; ovipositor short and with a semicircular ventral piece (Fasc. 152, p. 183) .... Procontarinia Kieff. & Cec.

hh Third vein not interrupting the margin at its union with costa

i Ventral plate not longer than the dorsal, bilobed; terminal clasp segment large, pubescent; ovipositor long (B. 202, p. 120).............. Thecodiplosis Kieff.[2]

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[1] Rübsaamen has limited this genus to species with the lobes of the ovipositor not pubescent, whereas those with pubescent lobes are referred to the genus Atylodiplosis Rübs. (Rübs. '17, p. 87), type acetosellae Rübs. and Diadaulus (Rübs. '17, p. 87), type linaria Wtz., the former with the pulvilli longer than the claws and the lobes of the ventral plate broad; palpi triarticulate; while the latter has the pulvilli as long or shorter than the claws, the lobes of the ventral plate more or less pointed and the palpi quadriarticulate.

[2] A study of considerable American and some European material raises doubts as to the validity and utility of these distinctions in relation to both Contarinia and Thecodiplosis.

Rübsaamen has restricted this genus to species having triarticulate palpi, the margin not interrupted at the tip of the third vein and has erected Anisostephanus (Rübs. '17, p. 87), type betulinum Kieff. for a species with quadriarticulate palpi and an interruption of the margin at the tip of the third vein; both genera with the third vein uniting with the margin beyond the apex of the wing.

ii Ventral plate linear, much longer than the dorsal, emarginate; terminal clasp segment slender, smooth; ovipositor slightly produced (Fasc. 152, p. 185)...........Sitodiplosis Kieff.

gg Third vein uniting with the margin beyond the apex of the wing

h Terminal clasp segment of the male short, thick, pubescent; fourteenth antennal segment of the female with a large conical appendage (Fasc. 152, p. 176) Stephodiplosis Tav.

hh Terminal clasp segment moderately long, not pubescent; fourteenth antennal segment of the female without a conspicuous appendage (Fasc. 152, p. 177).......... Syndiplosis Rübs.

bb Some flagellate antennal segments of the male cylindrical

c All the flagellate antennal segments of the male cylindrical

d Claws toothed, curved at almost right angles

e Circumfila low; terminal clasp segment slender, the lobes of the dorsal plate rounded (Fasc. 152, p. 246) Holobremia Kieff.[1]

dd Claws simple

e Ventral plate a little longer than the dorsal plate; terminal clasp segment short, plainly swollen near the middle (Fasc. 152, p. 248)............Geisenheyneria Rübs.[1]

ee Ventral plate linear, emarginate apically, much longer than the dorsal plate; terminal clasp segment slender (Fasc. 152, p. 247)..............Monodiplosis Rübs.[1]

eee Dorsal plate divided; the lobes triangular; ventral plate a little longer, linear, rounded; terminal clasp segment somewhat enlarged, slightly arched; ovipositor not produced (Fasc. 152, p. 247)....Stroblophila Kieff.

cc Terminal flagellate antennal segments cylindric

d Circumfila with a length one-half the setae, the stems shorter than the nodes, those of the two terminal segments wanting or almost wanting, the terminal clasp segment large, greatly swollen; ventral plate entire (Fasc. 152, p. 174).... Halodiplosis Kieff.[1]

dd Circumfila with short bows, the thirteenth and fourteenth segments with short stems; terminal clasp segment slender; ventral plate longer than the dorsal and deeply emarginate (Fasc. 152, p. 246)..........Ametrodiplosis Rübs.

ddd Circumfila rudimentary

e Costa with a fusiform swelling basally, the basal stem of the fifth antennal segment with a length equal to its diameter; ventral plate much longer than the dorsal, much constricted and with a deep, straight incision, the lobes pointed; terminal clasp segment arched and long (Fasc. 152, p. 143)..........Cyrtodiplosis Kieff.

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[1] Location provisional.

ee Costa not thickened basally, the basal stem of the fifth antennal segment with a length equal to the basal enlargement, the ventral plate sublinear, longer than the dorsal, narrowly incised and with two straight lobes; terminal clasp segment long, slender, curved (Fasc. 152, p. 248)..............Anthodiplosis Kieff.

aa Palpi triarticulate

b Basal clasp segment with a conspicuous triangular process apically

c The lobe long, narrowly triangular, the terminal clasp segment normal (B. 202, p. 129)....................Dentifibula Felt

cc The lobe broadly rounded, not greatly produced, terminal clasp segment irregular, pectinate apically (B. 202, p. 132)......... Pectinodiplosis Felt

b Basal clasp segment without a process apically

c Terminal clasp segment stout, with a length about 3 times its diameter; ventral plate almost truncate (Fasc. 152, p. 185) Myricomyia Kieff.

cc Terminal clasp segment ellipsoidal, pubescent

d Ovipositor short, the length about equal to its diameter (Fasc. 152, p. 186)...................Zeuxidiplosis Kieff.

dd Ovipositor long, striate (Fasc. 152, p. 174)............... Stenodiplosis Reut.

aaa Palpi uniarticulate

cc Third vein uniting with the margin well beyond the apex, the dorsal and ventral plates both long and emarginate (Phil. J. Sci. 13:289)............................Kronodiplosis Felt

Trifila

a Claws toothed on all the legs

b Palpi quadriarticulate

c Circumfila with one or more greatly produced bows or loops having a length 5 to 10 times that of the enlargement and extending at approximately right angles to it[1]

d Three well-developed circumfila on each flagellate antennal segment

e The three circumfila irregular, the pulvilli rudimentary, the ventral plate spatulate (Fasc. 152, p. 159)...... Tribremia Kieff.

ee Two circumfila irregular and one regular, the circumfilum on the basal enlargement with two greatly produced loops and the one on the distal enlargement with a shorter bow or loop

f Pulvilli a little shorter than the claws (Fasc. 152 p. 161)..........................Isobremia Kieff.

ff Pulvilli rudimentary or wanting (Fasc. 152, p. 159) Cryptobremia Kieff.

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[1] Trilobia Del Guer., Uncinulella Del Guer. and Trilobiella Del Guer., very probably belong in this group of predaceous forms and subsequent rearings may show them to be referable to earlier established genera.

eee One circumfilum irregular and with a bow or loop greatly produced, the other two circumfila regular, the style simple

f Ventral plate large, oval, as long as or a little longer than the dorsal; pulvilli equal to or longer than the claws (B. 202, p. 133)....Aphidoletes Kieff.

dd Two well-developed, irregular circumfila; basal circumfilum on the distal enlargement forming a low band; pulvilli small

e Legs clothed with hairs, the style not arched

f Flagellate antennal segments with the distal enlargement produced, the basal subglobose, the ventral plate linear, not emarginate and as long as the simple style (B. 202, p. 141)....Bremia Rond.

ff Flagellate antennal segments with two subglobose enlargements

g Ventral plate linear, emarginate, much shorter than the style (Fasc. 152, p. 158).......... Homobremia Kieff.

gg Ventral plate broad, with two widely separated linear processes on the posterior lateral angles and extending to the tip of the truncate style (Natal Mus. Ann. 4:494)...Heterobremia Felt

ee Legs clothed with scales, the style strongly arched basally

f Ventral plate shorter than the dorsal, linear and rounded distally (Fasc. 152, p. 164)........... Lepidobremia Kieff.

cc Circumfila all about equal, nearly regular and without one or more greatly produced bows or loops

d Basal clasp segment with a basal lobe

e Flagellate antennal segments trinodose; terminal clasp segment much produced; plainly longer than the basal clasp segment; ovipositor short and with large, orbicular lobes (B. 202, p. 145)....Youngomyia Felt

ee Flagellate antennal segments binodose; terminal clasp segment not greatly produced

f Ventral plate linear, a little longer than the dorsal plate; ovipositor moderately short and with long densely haired lobes (Fasc. 152, p. 202).......... Therodiplosis Kieff.

ff Ventral plate ovate; ovipositor of the female short (Rubs. '15 a, p. 452)......Dactylodiplosis Rübs.

dd Basal clasp segment without a distinct basal lobe

e Claws curved nearly at right angles

f Palpi long or moderately long

g Ventral plate linear, broadly emarginate; dorsal plate long, broad, triangularly emarginate, the circumfila slightly irregular, the style with filiform branches (Fasc. 152, p. 193)..... Plesiobremia Kieff.

gg Ventral plate moderately long, broadly emarginate; dorsal plate rather long, broad, deeply and triangularly emarginate, the lobes triangular, ovipositor short (U. S. N. M. P. No. 2452, p. 1–2, 1922)....Cleodiplosis Felt

ggg Ventral plate long, narrowly rounded apically; dorsal plate broad, deeply and broadly emarginate; the lobes moderately narrow apically (Fasc. 152, p. 235).......Dichodiplosis Rübs.

gggg Dorsal and ventral plates short, broad and deeply emarginate (B. 202, p. 150)......... Thomasia Rübs.

ff Palpi short, the second antennal segment with a length one-half greater than its diameter (Fasc. 152, p. 170).......................Collinia Kieff.

ee Claws not strongly curved basally and therefore not forming almost a right angle

f Circumfila with numerous loops, about twenty

g Lobes of the ventral plate linear and parallel; ovipositor rather short (Fasc. 152, p. 232).... Geodiplosis Kieff.

ff Circumfila loops short, the hairs 2 to 3 times longer

g Lobes of the ventral plate short, broadly rounded; ovipositor short (Fasc. 152, p. 234)........ Calodiplosis Tav.

fff Circumfilar loops normally long and not excessively numerous

g Cross vein well developed and nearly parallel with costa as in the Porricondylariae (Fasc. 152, p. 253)..................Lopesia Rübs.[1]

gg Crossvein not well developed and nearly parallel with costa as in the Porricondylariae

h Terminal clasp segment slender; lobes of the dorsal and ventral plates truncate; ovipositor short and with long, narrowly oval lobes (Fasc. 152, p. 235).......... Resseliella Seitn.

hh Terminal clasp segment stout; lobes of the dorsal and ventral plates narrowly rounded, the dorsal plate broadly, and the ventral plate deeply, emarginate; ovipositor long, with imperfectly divided lobes (Fasc. 152, p. 233)................ Harmandia Kieff.

ffff Genera known only as females and presumably belonging here in the key

g Ovipositor slightly protractile, the lobes long, curved, and with two or three longitudinal subventral rows of obtuse spines (B. 202, p. 151)...................Dicrodiplosis Kieff.

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[1] Included because of antennal structure although this insect belongs in the Porricondylariae.

gg Ovipositor about half the length of the abdomen, the lobes with a length about 6 times the width; mouth parts prolonged (Psyche 22:155) ....Delphodiplosis Felt

ggg Ovipositor moderately long, with a subcylindrical, dorsal part and a ventral oval plate with a narrowly triangular incision about one-fourth its length (Fasc. 152, p. 171)......... ....Schizodiplosis Kieff.

gggg Ovipositor short, with three subcircular lobes, the ventral a little smaller than the two dorsal (Fasc. 152, p. 189).........Cacoplecus Kieff.

ccc Circumfila, two well developed, nearly regular, the basal circumfilum on the distal enlargement forming a low band

d Mouth parts greatly produced with a length one-half greater than the height of the head; basal clasp segment with a distinct internal lobe basally; ovipositor short; the terminal lobes oval (Ent. Soc. Lond. Trans. p. 504, 1921).......... Farquharsonia Collin

bb Palpi triarticulate

c Basal clasp segment distinctly lobed

d Flagellate antennal segments of the male without sharply defined nodes, the basal portion of the stem almost obsolete, the circumfila moderately short and not greatly thickened (B. 202, p. 160)..............Peridiplosis Felt

cc Basal clasp segment not distinctly lobed

d Flagellate antennal segments of female subcylindric

e Male with three well-developed circumfila, though without greatly produced bows or loops

f Circumfila with the loops short, thick and very numerous, each stem with a length less than its diameter; palpi moderately long; pulvilli rudimentary; dorsal and ventral plates long, the latter deeply emarginate and with relatively narrow lobes (B. 202, p. 159)..........Kalodiplosis Felt

ff Circumfila with the loops only moderately numerous, not unusually thick

g Stems, each with a length about twice its diameter, the palpi greatly reduced; dorsal and ventral plates very short, both emarginate

gg Stems, each with a length less than twice the diameter, palpi moderately reduced, dorsal and ventral plates moderately long, broadly emarginate (Ent. Mo. Mag. 58:105, '22)............Mycocecis Edw.

h Ovipositor short, the terminal lobes narrowly oval, the dorsal and ventral plates short, emarginate (Phil. J. Sci. 13:290)........ Kamptodiplosis Felt *hh* Ovipositor about one-third the length of the abdomen, the basal portion long, stout, tapering, the lobes slender; male unknown (Phil. J. Sci. 13:291). . Heliodiplosis Felt

e Male with two long circumfila, the second rudimentary, the loops not numerous, the pulvilli shorter than the claws, the dorsal and ventral plates deeply and roundly emarginate (Broteria 15:33). . . . Roachadiplosis Tav.

dd Flagellate antennal segments of female, at least some, binodose

e Female with two low circumfila on the cylindric distal enlargement of the flagellate antennal segments, none on the basal swelling; ovipositor about one-half the length of the body (Psyche, 22:156). . . . . Epihormomyia Felt

bbb Palpi uniarticulate

c Crossvein well-developed and nearly parallel with costa; claws quadridentate (Fasc. 152, p. 254). . Allodiplosis Kieff. & Jorg.

cc Crossvein not well developed and nearly parallel with costa; claws bidentate; circumfila very conspicuous and low as in Asphondylia (Fasc. 152, p. 150). . . . . Frauenfeldiella Rübs.[1]

aa Claws on the anterior legs and sometimes those of the middle legs toothed, those of the posterior legs simple

b Palpi quadriarticulate

c Circumfila with one or more greatly produced bows or loops having a length 5 to 10 times that of the enlargement and extending at approximately right angles to it

d Two irregular circumfila, one regular

e Third and fourth antennal segments fused, pulvilli nearly equal to the claws, the ventral plate elongate, subcordate distally (Fasc. 152, p. 160). . . . Phaenobremia Kieff.

ee Third and fourth antennal segments not fused; claws as long as the pulvilli; ventral plate a little more compressed than the dorsal and all about the same length (Bib. Agr. Col. '18, p. 187, 191). . Rondaniella Del Guer.

dd One circumfilum irregular, two regular

e Pulvilli one-half the length of the claws; ventral plate straight, linear and much longer than the dorsal plate (Fasc. 152, p. 162). . . . . Monobremia Kieff.

cc Circumfila regular or nearly so and without greatly produced bows or loops

d Basal clasp segment lobed

e The lobe apical, setose or spinose; terminal clasp segment subapical (B. 202, p. 161). . . . . Lobodiplosis Felt

ee The lobe subbasal, glabrous; terminal clasp segment short and bidentate (Fasc. 152, p. 191). . . . . Antichiridium Rübs.

eee The lobe basal, setose or nearly glabrous

f Ventral plate or harpes strongly chitinized (B. 202, p. 166). . . . . Coquillettomyia Felt

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[1] Possibly belongs in the Asphondylariae

ff Ventral plate and harpes as in Lestodiplosis and not chitinized (B. 202, p. 170) .... Feltiella Rübs.

dd Basal clasp segment not distinctly lobed

e Terminal clasp segment subfusiform, distinctly dilated; harpes strongly chitinized and very complex (B. 202, p. 174) .... Karschomyia Felt

ee Terminal clasp segment not as above

f Claws curved nearly at right angles

g Ventral plate greatly elongate and emarginate apically; dorsal plate deeply cleft and triangularly emarginate (B. 202, p. 177) .... Clinodiplosis Kieff.

gg Ventral plate rounded apically; dorsal plate deeply and narrowly divided (Fasc. 152, p. 194) .... Oribremia Kieff.

ggg Ventral plate broad, broadly and roundly emarginate, as long as the dorsal plate, the latter deeply and triangularly emarginate (Fasc. 152, p. 194) .... Profeltiella Kieff.

ff Claws not strongly curved and therefore not forming almost a right angle

g Ventral plate almost linear, straight and much longer than the dorsal plate (Fasc. 152, p. 201) .... Acaroletes Kieff.

gg Ventral plate not greatly produced, lobes of the dorsal plate not divided, cleft or triangularly emarginate; female antennal segments with normal, low circumfila; ovipositor short

h Middle circumfilum of the male flagellate antennal segments normal (B. 202, p. 179) .... Mycodiplosis Rübs.

hh Middle circumfilum of the flagellate antennal segments of the male very short (Rübs. '17, p. 68) .... Trigonodiplosis Rübs.

ggg The female differs from Mycodiplosis in the two circumfila being produced as distinct and very short bows; male unknown (Fasc. 152, p. 241) .... Camptodiplosis Kieff.[1]

bb Palpi triarticulate[2]

c Claws not bent at nearly right angles; three well-developed circumfila

d Terminal clasp segment not greatly produced; ventral plate short and broad (B. 202, p. 204) .... Diadiplosis Felt

dd Terminal clasp segment greatly produced, with a length twice that of the basal clasp segment; ventral plate longer than the dorsal, moderately broad, rounded apically (N. Y. Ent. Soc. J. 23:180) .... Xiphodiplosis Felt

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[1] This genus, Baeodiplosis Kieff., and Alethediplosis Tav. are known only in the female and presumably fall here in the tabulation.

[2] Epihormomyia Felt (see p. 161) may fall here in the key.

cc Claws bent at nearly right angles; two well-developed and one rudimentary circumfilum; ventral plate linear, roundly emarginate apically (Fasc. 152, p. 167)..............Chelobremia Kieff.

aaa Claws simple or not toothed on any of the legs

b Palpi quadriarticulate

c The third vein uniting with the margin before the apex of the wing

d Wings hyaline

e Pulvilli as long or nearly as long as the claws

f Stems of the flagellate antennal segments mostly with a length less than the diameter; circumfila rather short; ventral plate deeply bilobed, not greatly produced (34th Rep't., p. 81) Arthrocnodax Rübs. ....(Feltodiplosis Kieff.)

ff Stems of the flagellate antennal segments rather long, circumfila moderately long, ventral plate much longer than the dorsal plate, slender, greatly enlarged apically, the distal portion with a width twice its breadth and slightly emarginate apically (Fasc. 152, p. 210)............Microdiplosis Tav.

fff Stems of the flagellate antennal segments with a length over twice the diameter, circumfila moderately long

g Dorsal and ventral plates oval, of equal length (Bib. Agr. Col. '18, p. 231)................. Adelgimyza Del Guer.

gg Dorsal lobe divided, the lobes long, triangular, the lower compressed and a little shorter than the preceding (Bib. Agr. Col. '18, p. 247).... Cecidomyela Del Guer.

ee Pulvilli one-half the length of the claws or less

f Terminal clasp segment swollen and long-haired basally, distally slender and smooth; ovipositor not produced (Fasc. 152, p. 244)....Silvestrina Kieff.

ff Male unknown; female with the pulvilli hardly one-third the length of the sickle-shaped claws (Fasc. 152, p. 156)................Planodiplosis Kieff.[1]

dd Wings densely brown-haired, with clearer spots; costa with black scales as in Lasioptera

e Antennal hairs finely denticulate; thorax densely covered with yellow scales (Fasc. 152, p. 145)............... Chrysodiplosis Kieff.

cc Third vein uniting with costa at the apex of the wing

d Claws as long as the pulvilli

e Wings hyaline

f Dorsal plate bilobed, the lobes rounded apically

g Ventral plate a little longer than the dorsal plate, straight, linear and slightly emarginate (Fasc. 152, p. 221).........Endopsylla Meij.

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[1] Location provisional.

gg Ventral plate about equal to the dorsal plate, broadly and roundly emarginate (Rübs. '17, p. 66)..................Aschistonyx Rübs.

ff Dorsal plate divided, the lobes subacute, sparsely setose and distinctly longer than the ventral plate, which latter is short, compressed basally and probably truncate (Bib. Agr. Col. '18, p. 157)........... Moreschiella Del Guer.

ee Wings bluish black, spotted with white

f Dorsal and ventral plates bilobed, the lobes large and rounded apically (Fasc. 152, p. 244)............. Doxodiplosis Kieff.

dd Claws plainly much longer than the pulvilli

e Metatarsus almost one-half the length of the second tarsal segment; dorsal plate bilobed; ventral plate linear and rounded apically; ovipositor short (Fasc. 152, p. 200)....................Plagiodiplosis Kieff.

ee Metatarsus presumably less than one-half the length of the second tarsal segment; ovipositor as long as the body; male unknown (Fasc. 152, p. 227)........... Orthodiplosis Kieff.

ccc Third vein uniting with costa beyond the apex of the wing

d Circumfila irregular, one or more loops being greatly produced

e Wings hyaline [1]

f Ventral plate much longer than the dorsal plate and rounded apically (Fasc. 152, p. 169)........... Hadrobremia Kieff.

ff Ventral plate longer than the dorsal, bilobed (Fasc. 152, p. 168)...................Anabremia Kieff.

ee Wings yellow with black spots

f Legs spotted, thickly scaled; pulvilli nearly as long as the claws (Fasc. 152, p. 166)................ Plutodiplosis Kieff.

dd Circumfila with short bows or wanting

e Wings hyaline

f Some of the flagellate antennal segments cylindric

g Circumfila rudimentary or wanting; tenth to fourteenth segments cylindrical; harpes somewhat inflated (34th Rep't, p. 92)........... Prodiplosis Felt

gg Circumfila distinct though low, all the flagellate or only the distal antennal segments cylindrical; male antennae about as long as the body; ovipositor short (34th Rep't, p. 94).... Caryomyia Felt [2]

ff Flagellate antennal segments binodose in the male

g Stems shorter than the enlargement, sometimes transverse

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[1] Tricholaba Rübs. (Rübs. '17, p. 60) appears to fall in this group.

[2] This genus probably belongs in the Asphondylariae.

h Stems very short, transverse; antennae about as long as the body; ovipositor short (34th Rep't, p. 94)..............
Caryomyia Felt[1]

hh Stems shorter than the enlargement, ovipositor long or moderately long

i Wings very narrow, with a length about 4 times the width, the stems of the flagellate antennal segments with a length not over twice the diameter, the genitalia large, the ovipositor with a length about one-third that of the abdomen (Indian Ent. Mem. 8:6)...
Raodiplosis Felt

ii Wings not extremely narrow, the stems of the fifth antennal segment frequently with a length over twice their diameters; genitalia not unusually long, the ovipositor long (Fasc. 152, p. 222)..........Macrodiplosis Kieff.

hhh Stems as long or longer than the enlargement, ovipositor short (Treubia, 2:89)
............Thorodiplosis Felt

fff Flagellate antennal segments probably binodose in the male, this sex being unknown

g Ovipositor short, the lobes bearing lateral or ventral rows of heavy, truncate or club-shaped processes (Fasc. 152, p. 157)........
Ctenodiplosis Kieff.

gg Ovipositor short, the lobes without conspicuous processes

h Pulvilli as long as the claws

i Basal flagellate antennal segments of female cylindrical (U. S. N. M. P. 48:208).........Eohormomyia Felt

ii Basal flagellate antennal segments of female plainly binodose (N. Y. Ent. Soc. J. 23:182)...Androdiplosis Felt

hh Pulvilli rudimentary (Fasc. 152, p. 201)...
Diplecus Kieff.

ee Wings spotted

f Terminal clasp segment very slender, subfiliform and smooth, the ovipositor short (Fasc. 152, p. 195)...
Nanodiplosis Kieff.

ddd Circumfila well developed and not conspicuously irregular, the loops mostly as long as or longer than the diameter of the enlargement

e Claws bent at nearly right angles

f Basal clasp segment lobed

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[1] This genus probably belongs in the Asphondylariae.

g Terminal clasp segment slender, curved, the ventral plate straight, pubescent (Fasc. 152. p. 231)..................Octodiplosis Giard

gg Terminal clasp segment as long as the basal clasp segment, enlarged and bilobed apically; ventral plate almost linear and rounded apically (Fasc. 152, p. 190)......Trichodiplosis Kieff.

ggg Terminal clasp segment distinctly shorter than the basal clasp segment, moderately slender.

h Dorsal plate narrow, narrowly rounded apically, lobe of basal clasp segment triangular (Broteria 16:80)........Charidiplosis Tav.

hh Dorsal plate triangularly emarginate, lobe of basal clasp segment long (Broteria 20:148).
Theatodiplosis Tav.

ff Basal clasp segment not lobed

g Ventral plate long, slender, slightly expanded and roundly emarginate apically; dorsal plate short, triangularly emarginate (34th Rep't, p. 118)....................Giardomyia Felt

gg Ventral plate long, broad, very deeply and broadly emarginate; dorsal plate deeply and roundly emarginate (34th Rep't, p. 122)....
Hyperdiplosis Felt

ggg Ventral plate large, long and roundly excavated, dorsal plate bilobed, the lobes obliquely truncate (Fasc. 152, p. 239)................
Mycetodiplosis Kieff

gggg Male unknown, female with the ovipositor short, the pulvilli rudimentary (Fasc. 152, p. 251)..[1]
Chaetodiplosis Kieff.,

ee Claws not bent at right angles

f Basal clasp segment lobed

g The lobe apical

h The lobe very long, curved, setose; terminal clasp segment swollen basally (34th Rep't, p. 127)................Epidiplosis Felt

hh The lobe triangular; terminal clasp segment short, greatly constricted near the middle and enormously swollen and recurved apically (34th Rep't, p. 126)..........
Metadiplosis Felt

hhh The lobe small, densely haired; basal clasp segment with a length one-half that of the abdomen; circumfila each with twenty-six loops (Fasc. 152, p. 141)...............
Coelodiplosis Kieff.

hhhh The lobe membranous and extending from the basal clasp segment to the dorsal

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[1] See also under *gggggg* on page 169.

plate; terminal clasp segment with a similar membranous expansion (Fasc. 152, p. 188)............Tristephanus Kieff.

gg The lobe basal

h The lobe obtuse

i Ventral plate long, broad, broadly rounded; claws a little longer than the pulvilli (Fasc. 152, p. 152)......... Orseoliella Kieff.

ii Ventral plate short, deeply bilobed; claws much longer than the pulvilli (Fasc. 152, p. 232)..Isodiplosis Rübs.

hh The lobe triangular

i Anterior legs with the underside of the tibiae and the first two tarsal segments with erect groups of hairs (Fasc. 152, p. 199)........Lamprodiplosis Kieff.

ii Anterior legs without conspicuous groups of hairs

j Ventral plate narrowly rounded

k Wings spotted (34th Rep't, p. 128)..Lestodiplosis Kieff.

kk Wings not spotted (Fasc. 152, p. 198)..Coprodiplosis Kieff.

jj Ventral plate deeply and roundly emarginate

k Ventral plate lobes long, hairy and decurved (Rübs. '15 a, p. 469)....Iatrophobia Rübs.

jjj Ventral plate long, broad, broadly rounded, lobes obtuse (Rübs. '15 *a*, p. 467).Schismatodiplosis Rübs.

ff Basal clasp segment not conspicuously lobed

g Basal enlargement of the trinodose flagellate antennal segments with two circumfila, the distal with but one

h Ventral plate sublinear, tapering, rounded apically and much longer than the dorsal plate (N. Y. Ent. Soc. J. 19:61)........ Xenodiplosis Felt

gg Anterior femur of the male plainly enlarged, it being 3 times the size of the tibia

h Terminal clasp segment as long as the basal; ovipositor long, with a conical, fleshy apex (Fasc. 152, p. 140)....Eumerosema Kieff.

ggg Antennal segments plainly trinodose

h Dorsal plate divided, its lobes orbicular (34th Rep't, p. 152)..Obolodiplosis Felt.

gggg Antennal segments short, thick, the stems transverse, the enlargements short, broad *h* Circumfila fine, rather short, each with numerous (about 20) loops; genitalia moderately stout, dorsal and ventral plates bilobed (34th Rep't, p. 155)...... Retinodiplosis Kieff.

ggggg Without the striking characters listed under *g* to *gggg*

- *h* Ventral plate linear, rounded apically
  - *i* Dorsal plate much shorter than the ventral plate, the lobes truncate (34th Rep't, p. 162)..Parallelodiplosis Rübs.
  - *ii* Dorsal plate much longer than the ventral plate (Fasc. 152, p. 231)..... Blastodiplosis Kieff.
- *hh* Ventral plate long, spatulate
  - *i* Dorsal plate moderately long, broad, deeply and triangularly emarginate, the lobes broad, obliquely and roundly emarginate (Fasc. 152, p. 187).... Hypodiplosis Kieff.
- *hhh* Ventral plate greatly produced and lobed
  - *i* Ventral plate broadly and roundly emarginate, the lobes diverging and broad (Fasc. 152, p. 230).......... Brachydiplosis Rübs.
  - *ii* Ventral plate roundly and deeply emarginate, the lobes long, narrow; the ovipositor short (Broteria 15:22, 149)...............Eudiplosis Tav.
- *hhhh* Ventral plate broad and broadly or triangularly emarginate
  - *i* Lobes of the ventral plate linear and parallel
    - *j* The male with 14 and the female with 13 antennal segments; claws almost equal to the pulvilli; ovipositor long and filiform (Fasc. 152, p. 225)....Delodiplosis Tav.
    - *jj* Male and female with 14 antennal segments; claws as long as the pulvilli; ovipositor stout and long (Fasc. 152, p. 229)........... Phyllodiplosis Kieff.
  - *ii* Lobes of the ventral plate not linear and parallel
    - *j* Dorsal plate deeply incised, the lobes narrowly rounded, the terminal clasp segment with a broadly chitinized, serrate margin (34th Rep't p. 150)............ Paradiplosis Felt

jj Dorsal plate deeply and roundly incised, the lobes rather broadly rounded, terminal clasp segment moderately short, stout, dentate and apparently not serrate (Broteria 16:76) . Styracodiplosis Tav.

jjj Dorsal plate not incised or very narrowly emarginate

k Genitalia large, with a length one-fourth that of the abdomen; ventral plate lobes slender and diverging; ovipositor short and with subtriangular lobes (Fasc. 152, p. 223) . . Plesiodiplosis Kieff.

kk Genitalia smaller, ovipositor not as described above

l Terminal clasp segment large, swollen near the middle and hairy; ovipositor long, with short hairs and short haired lobes (Fasc. 152, p. 224) Plemeliella Seitn.

ll Terminal clasp segment with a length one-half that of the basal segment and slightly tapering; ovipositor conical and with a length twice its basal diameter (Fasc. 152, p. 224).Pachydiplosis Kieff.

lll Terminal clasp segment as long or nearly as long as the basal clasp segment and smooth; ovipositor moderately long and with lobes. (34th Rep't, p. 175) . . . . . . Itonida Meig.

gggggg Genera known only as females[1]

h Cross vein present and well developed; pulvilli one-half as long as the claws; ovipositor small, produced (Fasc. 152, p. 251) . . . . Liebliola Kieff. & Jorg.[2]

hh Cross vein not well developed

i Ovipositor several times the length of the body; pulvilli less than one-half the length of the claws (Fasc. 152, p. 226) . . . . Xylodiplosis Kieff.

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[1] Location provisional.

[2] Probably referable to the Porricondylariae.

- *ii* Ovipositor as long as the body, the latter covered with scales; pulvilli rudimentary (Fasc. 152, p. 227).... Lepidodiplosis Kieff.
- *iii* Ovipositor short, pulvilli rudimentary (Fasc. 152, p. 251)................ Chaetodiplosis Kieff.
- *iiii* Ovipositor short, the terminal lobes slender and with a length nearly equal to a body segment (Psyche 22:154)...........Ouradiplosis Felt

- *bb* Palpi triarticulate
  - *c* Circumfila with short bows or loops, their length being one-half the diameter of the enlargement or less
    - *d* Thorax plainly extending over and concealing the head, at least to a considerable extent
      - *e* Males with 15 to 27 or possibly more antennal segments, females with 14 or more antennal segments, the flagellate segments of the female usually strongly constricted; ovipositor short, species mostly large (34th Rep't, p. 209)............Hormomyia H. Lw.[1]
      - *ee* Male and female with 14 or 15 (Fifteenth rudimentary), antennal segments, the flagellate segments of the female cylindrical and mostly with three circumfila, the ovipositor moderately long, species medium to small (34th Rep't, p. 220)...........Trishormomyia Kieff.
    - *dd* Thorax not produced over the head to a marked degree
      - *e* Flagellate antennal segments of the male binodose
        - *f* Basal clasp segment unarmed
          - *g* Style not expanded apically and with the sides not strongly chitinized
            - *h* Third vein uniting with the margin well beyond the apex; wings long or rather long[2]
              - *i* Female with 3 circumfila on the flagellate antennal segments, ovipositor as long as the body (Fasc. 152, p. 203). Pseudhormomyia Kieff.
              - *ii* Female with 2 circumfila on the flagellate antennal segments; ovipositor not long (Fasc. 152, p. 205)...... Dyodiplosis Rübs.
            - *hh* Third vein uniting with the margin before or near the apex, wings rather short, broad; flagellate antennal segments of the male binodose and with very short

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[1] A study of Hormomyia H. Lw. and closely related forms leads us to believe that Proshormomyia Kieff. grades so closely into typical Hormomyia H. Lw. as to make it advisable to sink this name as a synonym. Paurosphondylus Rübs. (Rübs. '17, p. 59), type rosenhaueri Rübs., and Diplolaboncus Rübs. (Rübs. '17, p. 59), type tumorificus Rübs., are both open to question,

[2] Jaapiola Rübs. (Rübs. '14, p. 95) apparently falls in this series.

stems or cylindrical; male antennae about as long as the body; ovipositor short (34th Rep't, p. 94)............... Caryomyia Felt[1]

gg Style expanded apically and with the sides strongly chitinized

h Dorsal plate triangularly emarginate; ventral plate long, broad, broadly and roundly emarginate (Fasc. 152, p. 245)........ Massalongia Kieff.

ff Basal clasp segment with a spine mesially

g Pulvilli very small (Fasc. 152, p. 190)........ Microplecus Kieff.

gg Pulvilli nearly as long as the claws (Fasc. 152, p. 141)...................Holodiplosis Kieff.

ee Flagellate antennal segments of the male cylindrical, at least some

f Third vein uniting with the margin near the apex; wings rather short, broad, male flagellate antennal segments binodose, with short stems or cylindrical; male antennae about as long as the body; ovipositor short (34th Rep't p. 94)............... Caryomyia Felt[1]

cc Circumfila loops with a length equal to the diameter of the enlargement or longer

d Wings hyaline

e Basal clasp segment lobed

f Genitalia very long, slender, the length equal to two-thirds that of the abdomen (Fasc. 152, p. 199) Ischnodiplosis Kieff.

ff Genitalia moderate in size; ventral plate chitinized and denticulate (34th Rep't. p. 231)............ Odontodiplosis Felt

ee Basal clasp segment not distinctly lobed

f The third vein uniting with the margin before or at the apex of the wing

g Dorsal half of each eye segregated from ventral half and uniting on vertex to form a third eye group (Fasc. 152, p. 136). Trisopsis Kieff.

gg Eyes normal and not so widely separated

h Claws a little longer than the pulvilli

i Terminal clasp segment slender and smooth; dorsal and ventral plates bilobed; ovipositor short and with biarticulate lobes (Fasc. 152, p. 145) Tricontarinia Kieff.

ii Ovipositor large, short and with obtuse lobes (Fasc. 152, p. 188)............ Atrichosema Kieff.[2]

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[1] Probably referable to the Asphondylariae.

[2] Only the female is known; location provisional.

hh Claws small, much shorter than the pulvilli; ovipositor moderately long (Fasc. 152 p. 208).............Hygrodiplosis Kieff.[1]

ff Third vein uniting with margin beyond the apex of the wing

g Fifth antennal segment of the female with a slight enlargement and a peculiar sensory organ near the middle (Fasc. 152, p. 207).... Trissodiplosis Kieff.

gg Second antennal segment prolonged ventrally as an obtuse lobe; ovipositor short and with two long lobes (Fasc. 152, p. 146).......... Acodiplosis Kieff.

ggg Antennal segments normal, without unusual processes or organs

h Dorsal plate deeply and triangularly emarginate

i Ventral plate triangular, broadly and roundly emarginate; ovipositor long and the lobes long (Fasc. 152, p. 204) Taphodiplosis Kieff.

ii Ventral plate linear, straight, not emarginate; ovipositor moderately long and the lobes long (Fasc. 152, p. 209).........Haplodiplosis Rübs.[2]

iii Ventral plate linear, roundly emarginate; ovipositor aciculate and straight (Fasc. 152, p. 147).................. Centrodiplosis Kieff.

hh Dorsal plate deeply and narrowly incised

i Ventral plate broad and rounded; female unknown (34th Rep't, p. 234). Adiplosis Felt

ii Ventral plate narrowly emarginate; ovipositor moderately long, the lamellae deeply bilobed (Fasc. 152, p. 206). Löwiola Kieff.

hhh Genera provisionally placed here, the females only being known

i Two circumfila, each with 6 to 8 short bows; claws as long as the pulvilli (Fasc. 152, p. 207)................. Plecophorus Kieff.

ii The 2 circumfila are flat or nearly so, otherwise as in Plecophorus (Fasc. 152, p. 208)...........Aplecus Kieff.

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[1] Only the female is known; location provisional.

[2] Putoniella Kieff. will probably fall here in the table.

dd Wings spotted

- *e* Third vein uniting with the margin beyond the apex of the wing; pulvilli nearly as long as the claws (Fasc. 152, p. 166)....................Stictobremia Kieff.
- *ee* Third vein uniting with the margin at the apex of the wing; crossvein is present as in the Porricondylariae (Fasc. 152, p. 252)...........Ampeloscuta De. Stef.[1]

bbb Palpi biarticulate

- *c* Wings hyaline
  - *d* Circumfila short or only moderately long
    - *e* Thorax not produced over the head
      - *f* Circumfila apparently doubled in both sexes; third vein uniting with the margin at the apex of the wing; pulvilli as long as the claws; ovipositor short, with three lobes. (Fasc. 152, p. 150)...... Dichrona Rübs.
      - *ff* Circumfila not apparently doubled, low and with 8 to 10 small bows; third vein uniting with the margin beyond the apex of the wing; ovipositor large, conical and with 2 long lobes; male unknown (Fasc. 152, p. 151)........Perodiplosis Kieff.
    - *ee* Thorax produced over the head
      - *f* Circumfila not apparently doubled in the female; third vein uniting with the margin beyond the apex of the wing; pulvilli about one-half the length of the claws (Fasc. 152, p. 138)................ Dishormomyia Kieff.
  - *dd* Circumfila long or at least moderately long
    - *e* One or more basal antennal segments with an eccentric development or tooth
      - *f* Second antennal segment with a large lateral and oblique conical process; thorax produced as a cone in front but not covering the head (Fasc. 152, p. 249)..........Conodiplosis Kieff. & Jorg.
      - *ff* Second antennal segment prolonged ventrally as an obtuse lobe (Fasc. 152, p. 147).............. Neurodiplosis Kieff.
      - *fff* The stem of the first flagellate antennal segment of the male with a lateral tooth near its middle; dorsal plate narrowly incised, ventral plate longer and rounded apically (Fasc. 152, p. 151)...... Orseolia Kieff. & Mass.
    - *ee* Basal antennal segments without eccentric developments or processes
      - *f* Dorsal plate broad, broadly and roundly emarginate; ventral plate broad, triangular and slightly emarginate; ovipositor short, with 2 large, oval lobes bearing transverse rows of obtuse spines apically (Fasc. 152, p. 152)............Braueriella Kieff.

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[1] This genus may belong in the Heteropezinae.

ff Dorsal plate with the lobes obtusely truncate; ventral plate longer, linear, deeply and roundly emarginate; ovipositor short and with 2 lanceolate lobes (Fasc. 152, p. 154). . . . . Compsodiplosis Tav.

fff Dorsal plate triangularly divided; ventral plate long, broad and emarginate

g Ventral plate slightly emarginate; the style long, rounded apically and with the lateral margins strongly chitinized; the ovipositor long, with 2 lanceolate lobes (Fasc. 152, p. 245). Massalongia Kieff.

gg Dorsal plate rather deeply and roundly emarginate; the style long, rounded and without strongly chitinized margins; the ovipositor short, the lobes swollen basally, subtriangular, setose (Marcellia 17:61) . . . . Anadiplosis Tav.[1]

ffff Male unknown

g Ovipositor short, with a chitinized, falciform blade (Fasc. 152, p. 148) . . Jorgensenia Kieff.

gg Ovipositor moderately short, the 2 lobes elongate (Fasc. 152, p. 153) . . . . Courteia Kieff.

cc Wings marked with yellow and fuscous

d Fifth antennal segment with a stem one-half the length of the basal enlargement, which latter has a length 4 times its diameter; third and fourth segments free; third vein joins the margin beyond the apex of the wing; ovipositor short, the lobes angulate (U. S. N. M. P. 48:209) . . . . Scopodiplosis Felt

bbbb Palpi uniarticulate

c Circumfila apparently doubled in the male and female

d Pulvilli as long as the claws; ovipositor short and with three lobes (Fasc. 152, p. 150) . . . . Dichrona Rübs.

cc Circumfila not apparently doubled in the male and female

d Wings hyaline

e Fourteen antennal segments in both sexes, the nodes in the male unequal

f Dorsal and ventral plates deeply emarginate; ovipositor short, chitinous, falcate (34th Rep't, p. 236) Monarthropalpus Rübs.

ff Dorsal plate deeply and ventral plate broadly emarginate; ovipositor stout, with a length one-half that of the abdomen, the distal part thickly clothed with long, silky hairs (34th Rep't, p. 238) . . . . Onodiplosis Felt

fff Dorsal plate triangularly emarginate, ventral plate truncate; ovipositor short with 2 slender lobes (Broteria 15:162) . . . . Gnesiodiplosis Tav.

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[1] Rubsaamenodiplosis Tav. (Marcellia 17:61, 1918) may possibly be related to this genus.

ffff Dorsal plate deeply, broadly and roundly emarginate, the lateral margin extended ventrally; ventral plate broadly emarginate; ovipositor stout, with a length about two-thirds that of the abdomen (Indian Ent. Mem. 7:10)........Horidiplosis Felt

ee Thirteen antennal segments in the female, the third and fourth fused, the basal and distal nodes in the male flagellate antennal segments globose and ovoid respectively. Dorsal and ventral plates bilobed; ovipositor short, chitinous, aciculate (34th Rep't, p. 239)..................Cystodiplosis Kieff. & Jorg.

dd Wings black and yellow marked

e Basal and distal enlargements of the flagellate antennal segments of the male globose and cylindrical respectively. Harpes forming a spinose chitinous tube surrounding the style, ovipositor short, its lobes lanceolate (34th Rep't, p. 239)......Astrodiplosis Felt

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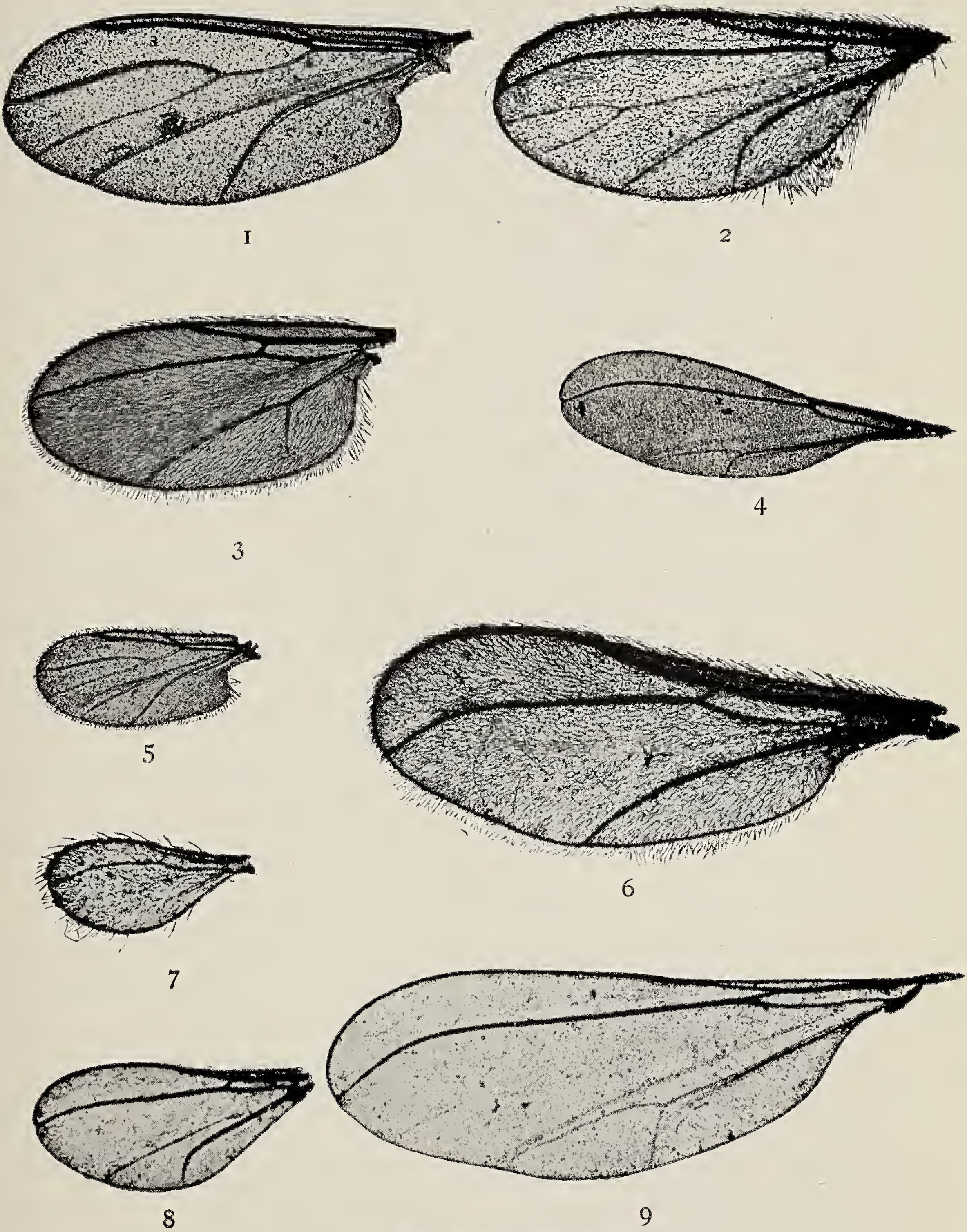
EXPLANATION OF PLATES

Plate I

Gall Midge Wings

1 Wing of Lestremia sylvestris Felt x 20
2 Wing of Catocha slossonae Felt x 20
3 Wing of Cordylomyia bryanti Felt x 20
4 Wing of Colpodia carolinae Felt x 20
5 Wing of Microcerata perplexa Felt x 20
6 Wing of Johnsonomyia rubra Felt x 20
7 Wing of Joannisia photophila Felt x 20
8 Wing of Winnertzia ampelopila Felt x 20
9 Wing of Porricondyla hamata Felt x 20

PLATE I



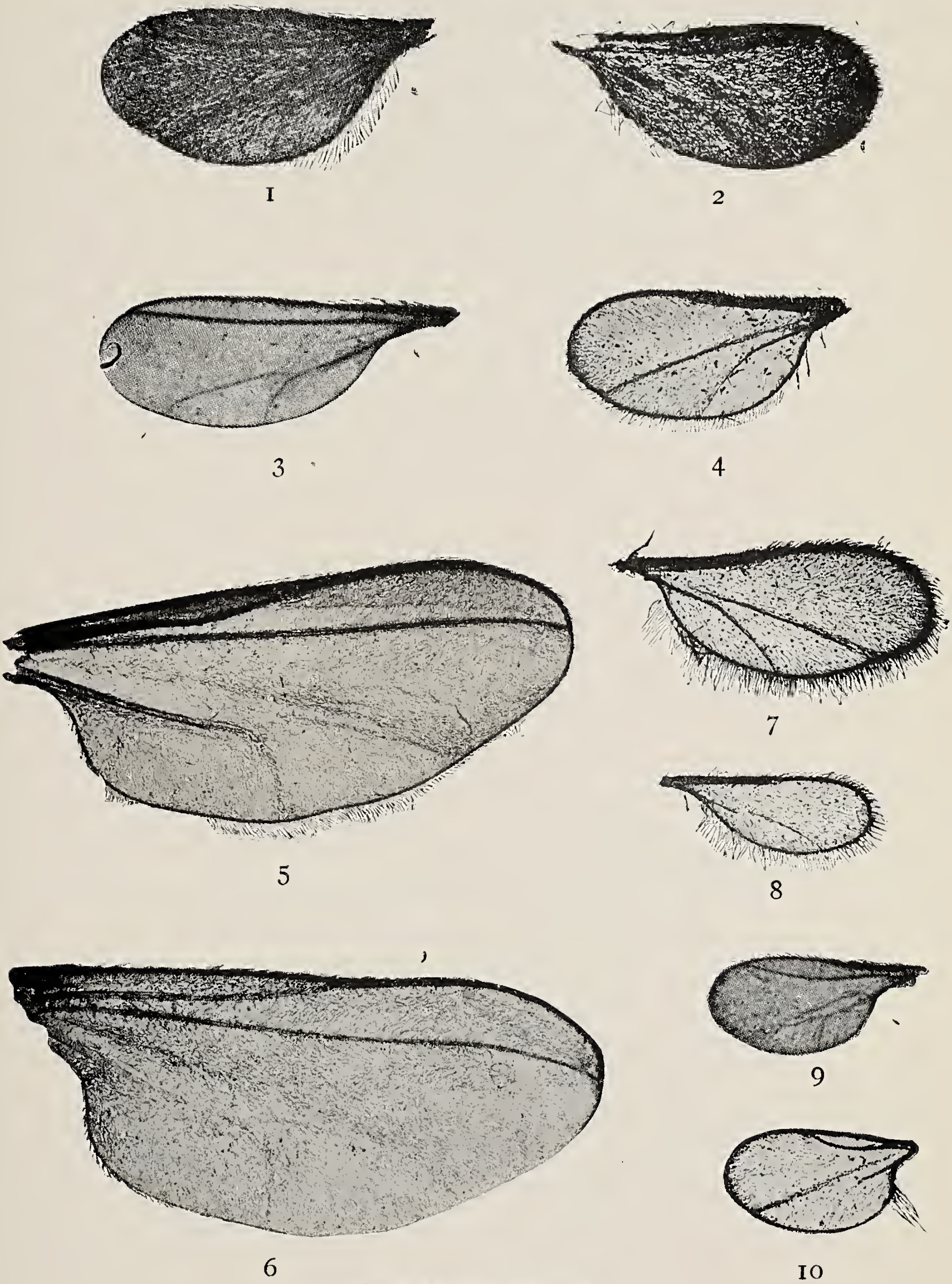
Gall Midge Wings

Plate 2

Gall Midge Wings

1 Wing of Lasiopteryx flavotibialis Felt x 20
2 Wing of Brachyneura americana Felt x 20
3 Wing of Dasyneura trifolii H. Lw. x 20
4 Wing of Asteromyia fuscoannulata Felt x 20
5 Wing of Rhabdophaga populi Felt x 20
6 Wing of Phytophaga rigidae O. S. x 20
7 Wing of Neolasioptera hibisci Felt x 20
8 Wing of Clinorhyncha millefolii Wachtl. x 20
9 Wing of Dasyneura photophila Felt x 20
10 Wing of Camptoneuromyia adhesa Felt x 20

PLATE 2



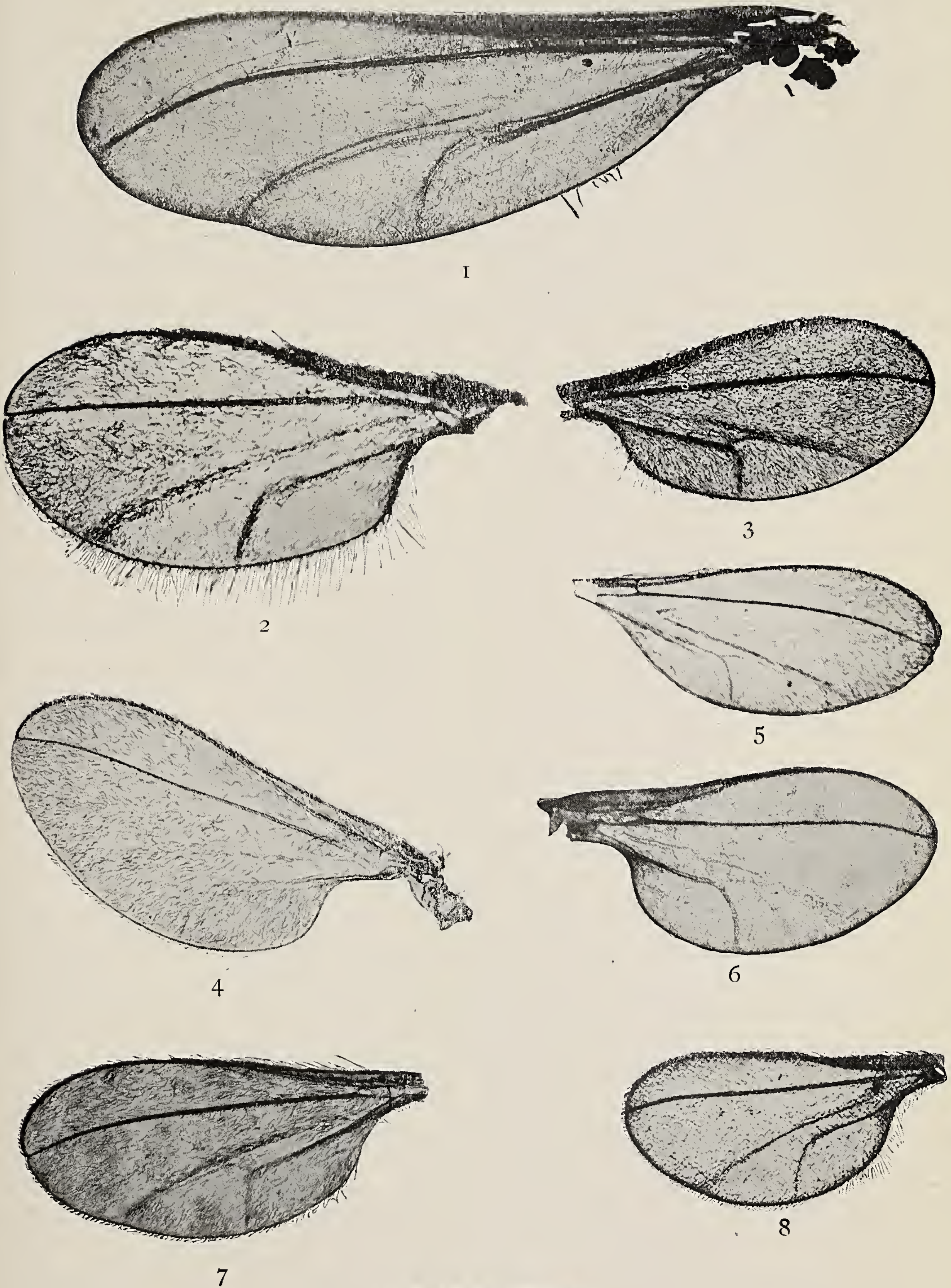
Gall Midge Wings

Plate 3

Gall Midge Wings

1 Wing of Hormomyia atlantica Felt x 20
2 Wing of Asphondylia monacha O. S. x 20
3 Wing of Schizomyia viburni Felt x 20
4 Wing of Cincticornia transversa Felt x 20
5 Wing of Bremia filicis Felt x 20
6 Wing of Lobopteromyia tiliae Felt x 20
7 Wing of Mycodiplosis alternata Felt x 20
8 Wing of Caryomyia tubicola O. S. x 20

PLATE 3]



Gall Midge Wings

Plate 4

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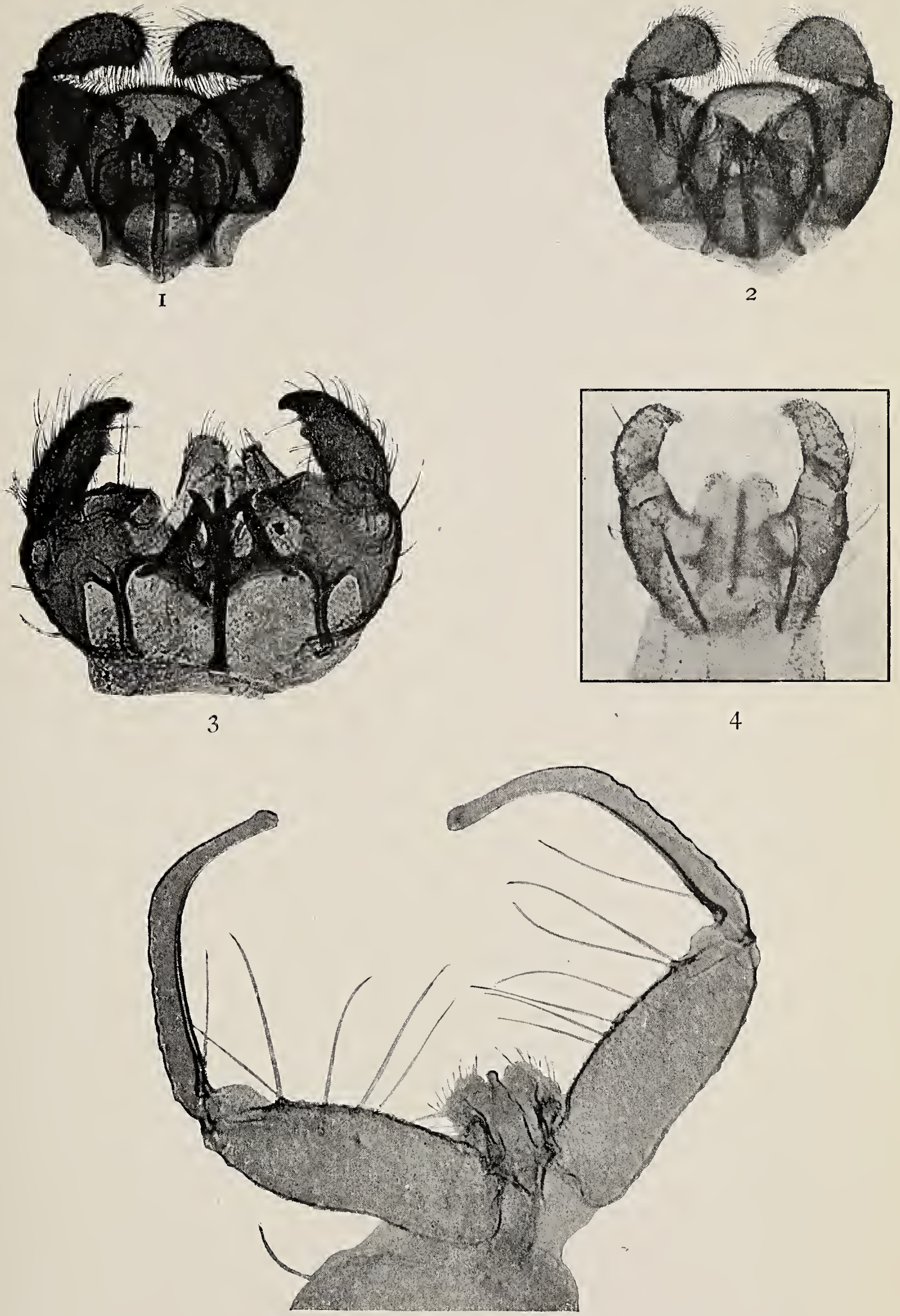
Gall Midge Genitalia

1 Genitalia of Monardia balsamicola Felt x 260
2 Genitalia of Monardia karnerensis Felt x 260
3 Genitalia of Colpodia carolinae Felt x 260
4 Genitalia of Leptosyna americana Felt x 260
5 Genitalia of Didactylomyia longimana Felt x 260

PLATE 4



Gall Midge Genitalia

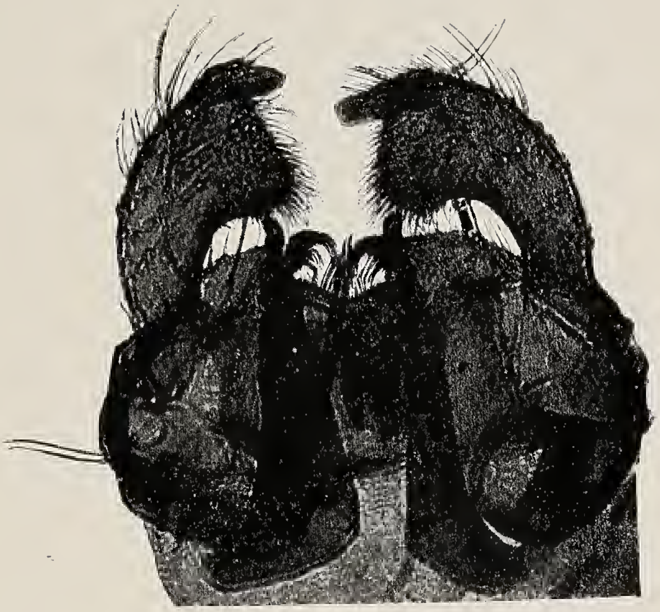
Plate 5

7

Gall Midge Genitalia

1 Genitalia of Porricondyla pini Felt x 260
2 Genitalia of Camptomyia multinoda Felt x 260

PLATE 5



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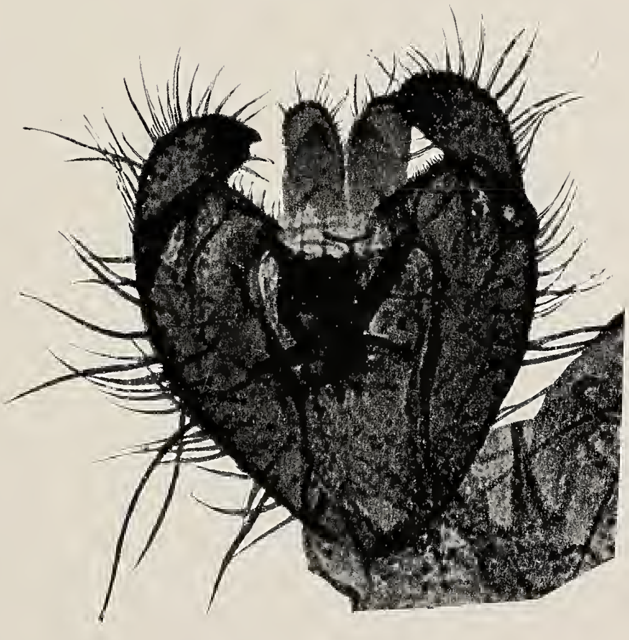

2

Gall Midge Genitalia

Plate 6

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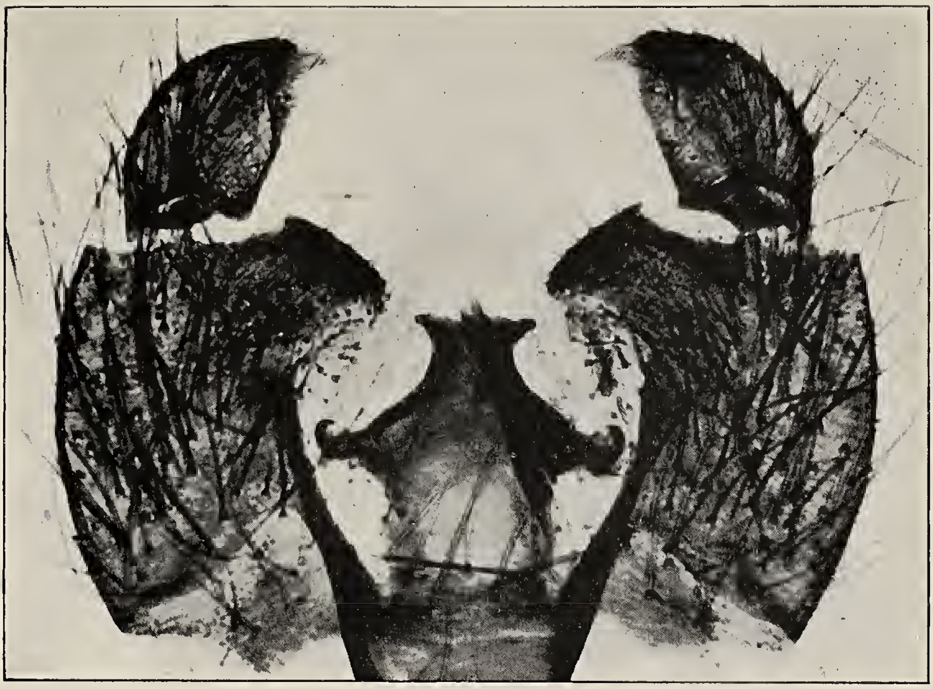
Gall Midge Structure

1 Male genitalia of Johnsonomyia fusca Felt x 180
2 Male genitalia of Rhopalomyia major Felt x 260

PLATE 6



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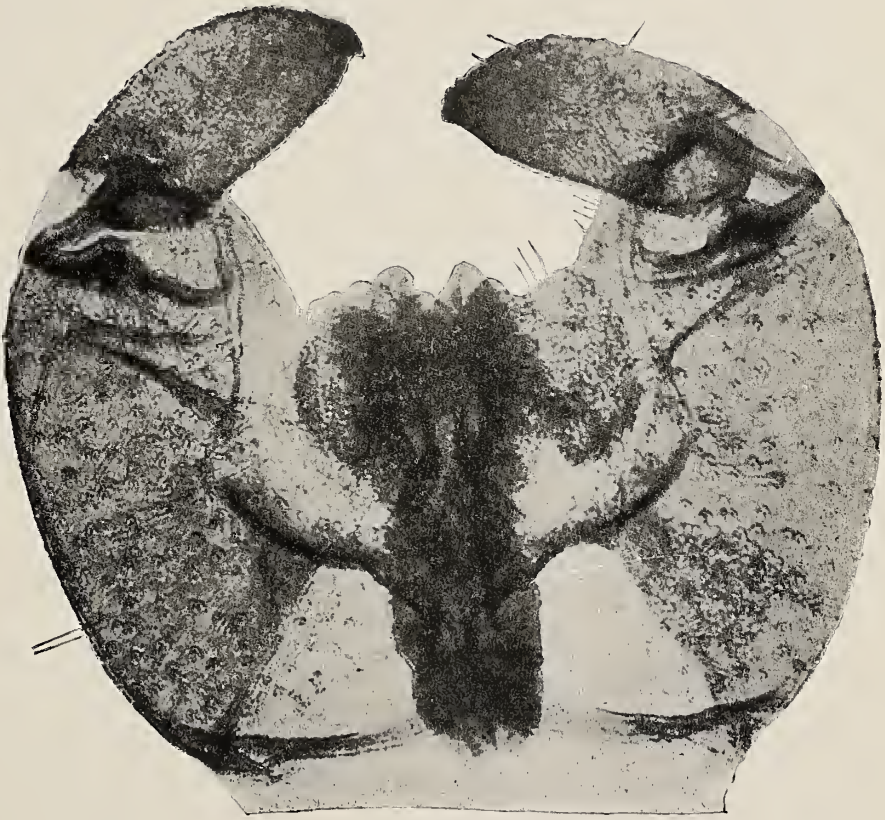


2

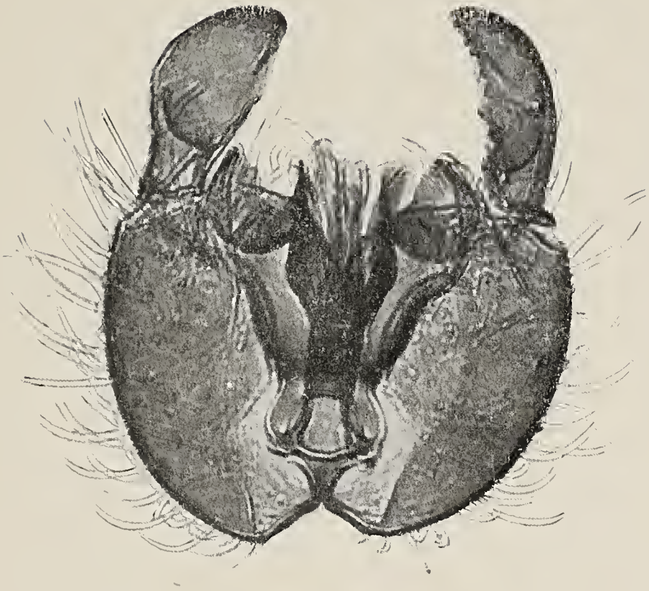
Gall Midge Genitalia

Plate 7

Gall Midge Genitalia

1 Genitalia of Karschomyia viburni Felt x 260
2 Genitalia of Lobodiplosis acerina Felt x 260

PLATE 7



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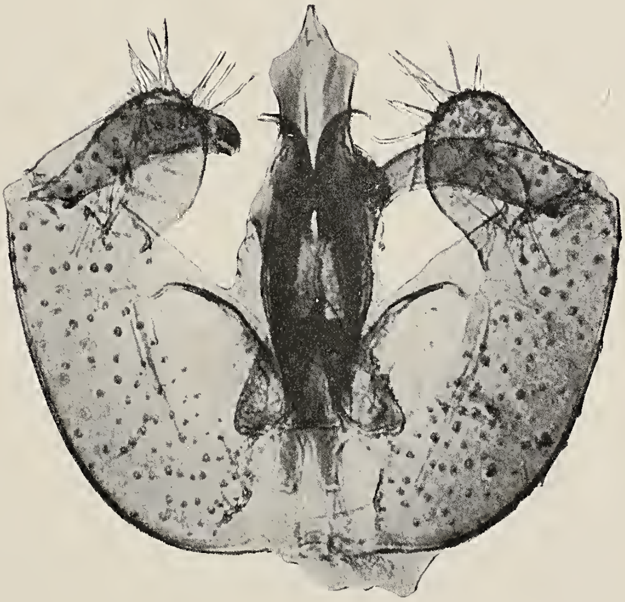


2

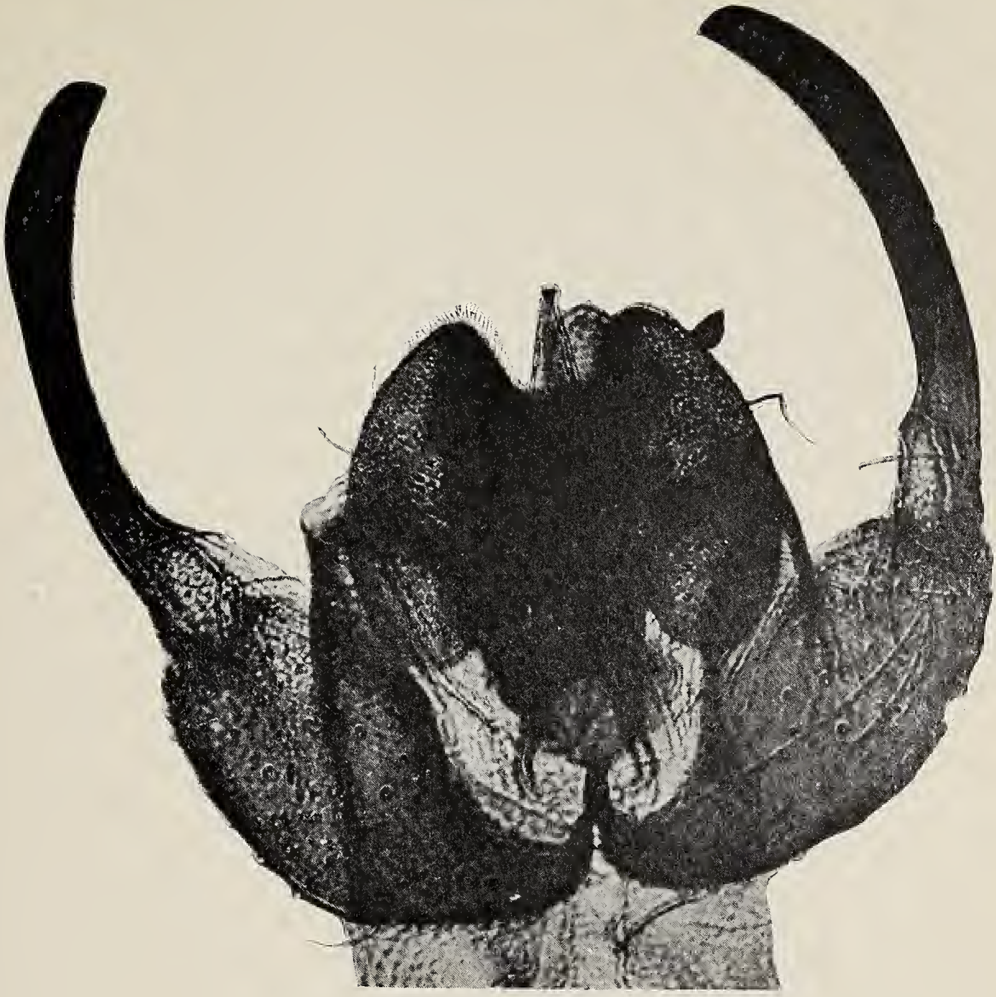
Gall Midge Genitalia

Plate 8

Gall Midge Genitalia

1 Genitalia of Obolodiplosis robiniae Hald. x 260
2 Genitalia of Youngomyia rubida Felt x 260

PLATE 8



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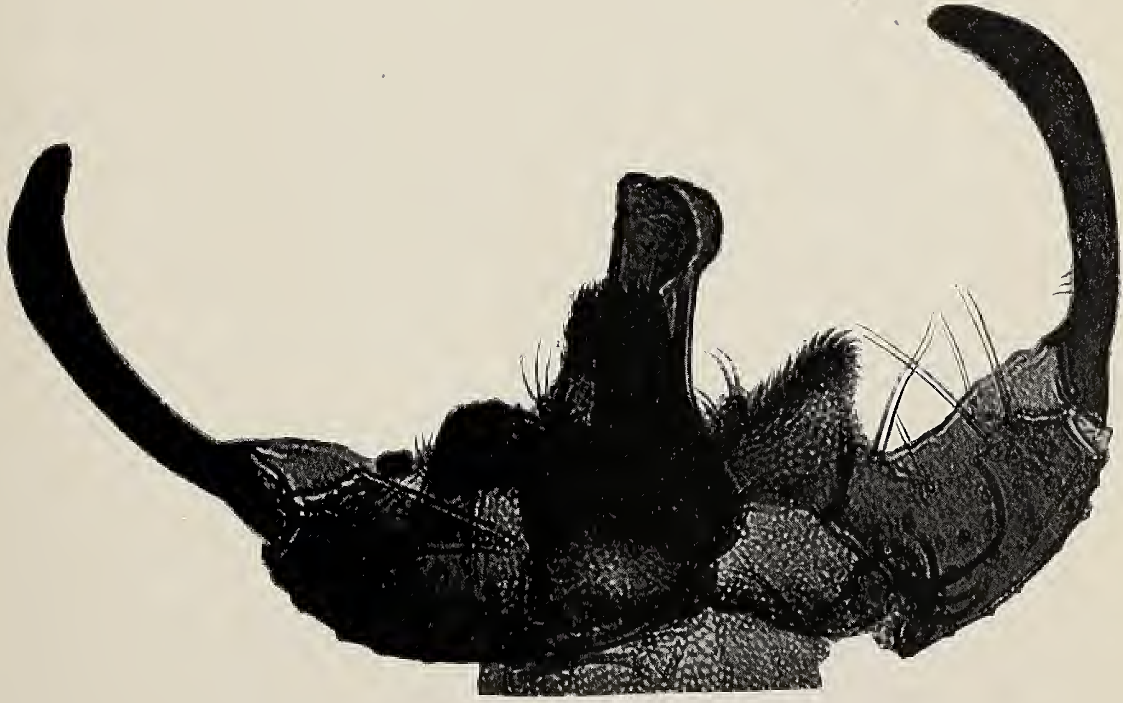

2

Gall Midge Genitalia

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With the author's compliments

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New York State Museum

John M. Clarke, Director

THE UTICA AND LORRAINE FORMATIONS OF NEW YORK

PART 1 STRATIGRAPHY

BY

RUDOLF RUEDEMANN

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Plate 1

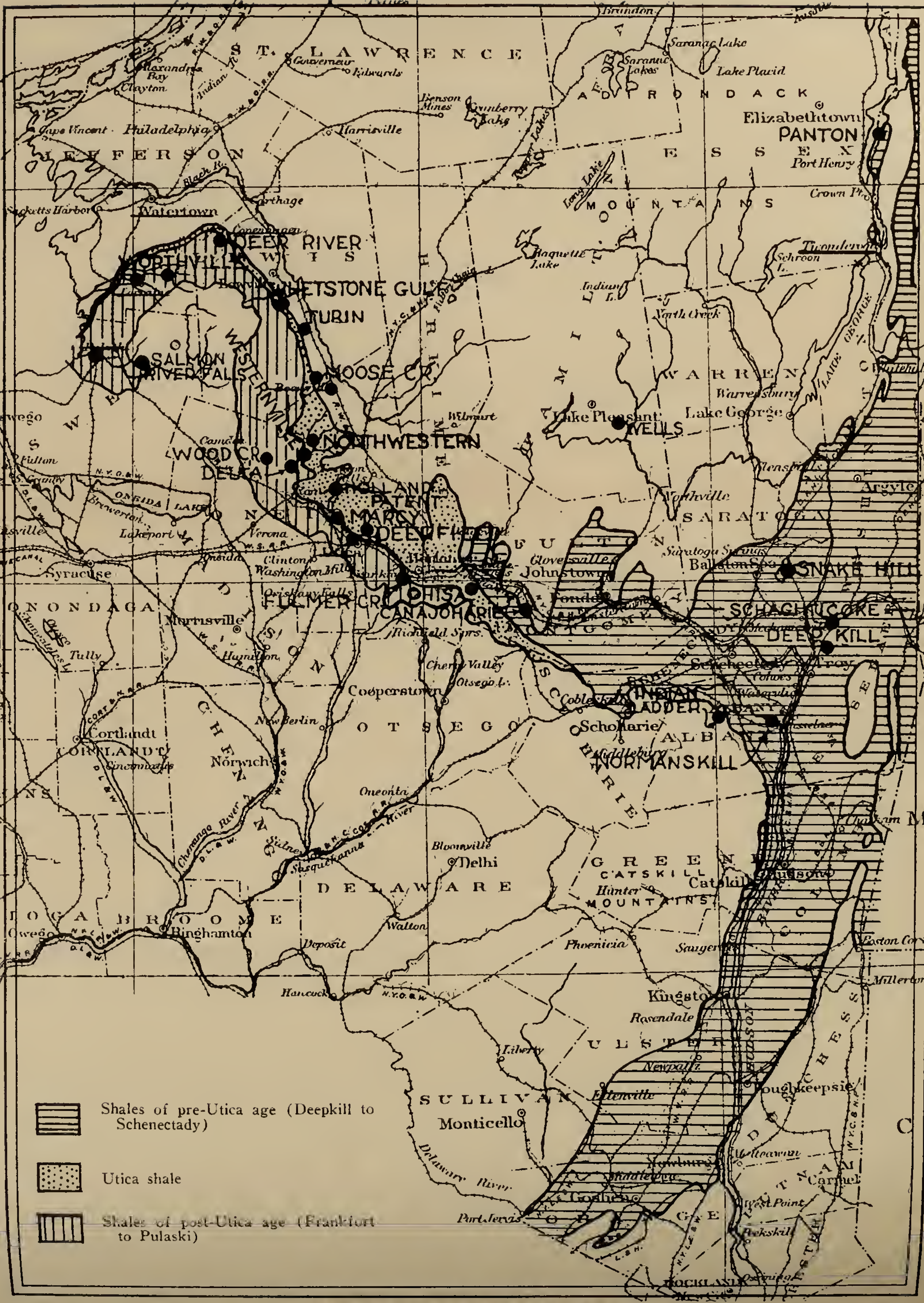

Chart of Ordovician shales of New York

Plate 1

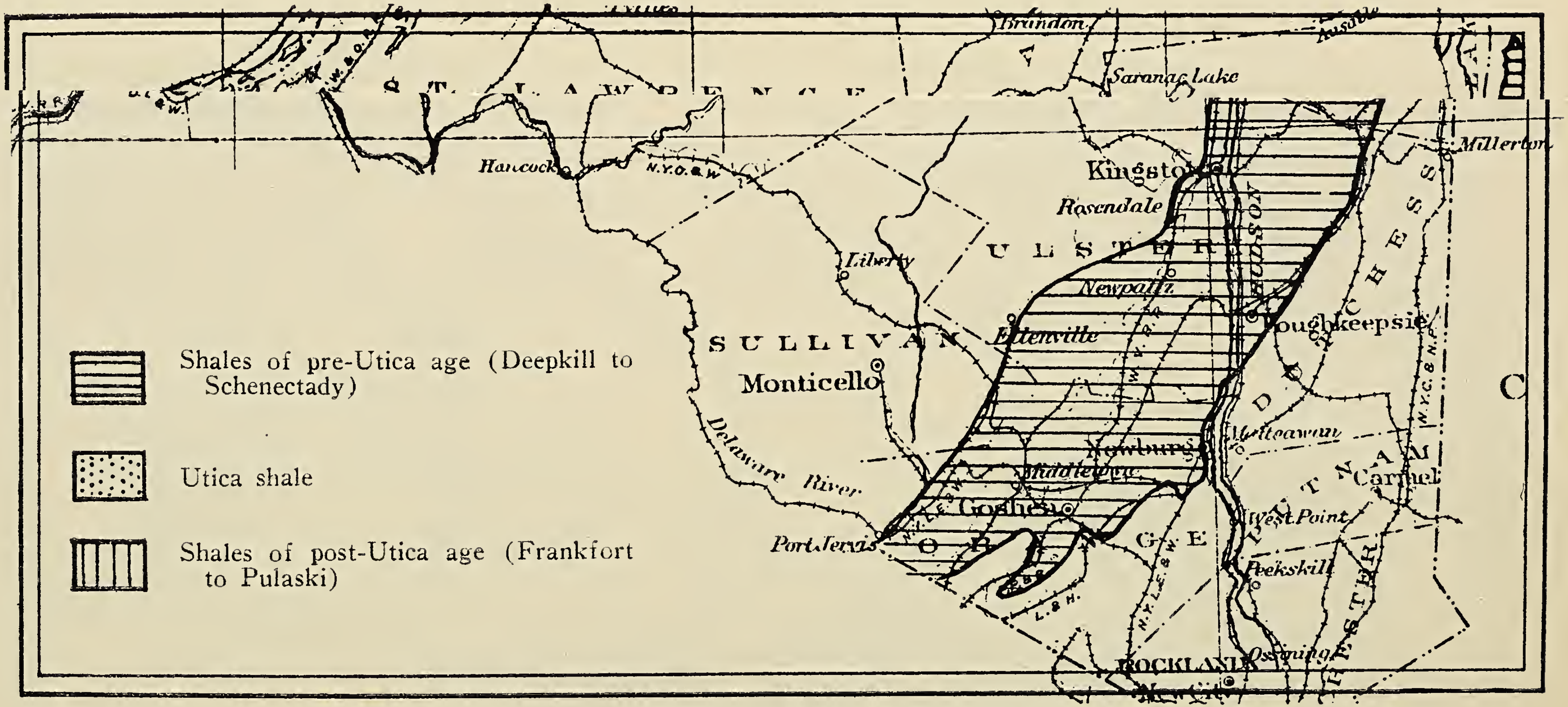

Chart of Ordovician shales of New York

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THE UTICA AND LORRAINE FORMATIONS OF NEW YORK

PART 1 STRATIGRAPHY

BY

RUDOLF RUEDEMANN

PREFACE

Twenty-five years ago, when the writer became interested in the black Utica shale of the Mohawk valley, he recognized the fact that there were successive zones of graptolites present in the Utica. He undertook to separate them but failed because the graptolite species and their varieties had not yet been properly distinguished, and black shales of very different ages were placed in the Utica formation.

These obstacles have now been gradually overcome; various black graptolite shales in the Hudson and Lower Mohawk valleys have been successively removed from the true Utica and properly correlated. It thus remains to take up the task dropped 25 years ago.

Interlocked with this problem of the black shales of the Mohawk valley, however, is that of the Frankfort and Lorraine beds, since beds of Lorraine and Frankfort aspect are likewise of very different age in the lower and upper Mohawk and Black river valleys; for in the first case (the Schenectady beds) they are of Trenton and Utica age, in the last (Black river valley) they are of late and post-Utica age. This complexity of the problem has led to a revision of the whole Utica, Frankfort and Lorraine stratigraphy of New York, which is presented herewith.

Dr E. O. Ulrich has unstintingly given of his wide perception and accurate knowledge of the Ordovician faunas and formations of the continent and especially of those of the adjoining Ohio basin. He is therefore responsible for the closer correlation of the New York and Ohio formations in this work, and for the authentic identification of western forms in the New York faunas.

In the prosecution of this work we have also constantly enjoyed the sympathetic support of Dr August F. Foerste who has aided us with specimens, with advice in the determination of fossils and as to his results and problems in Canada and the middle West. The Director of the State Museum and Science Division, Dr John M. Clarke, has shown continuous interest in the work, not only making its publication possible in a time of economic stress but also making accessible parts of Hall's correspondence that throw light on the intimately connected Taconic and Hudson River controversies. The National Museum and the United States Geologic Survey have, through Doctor Ulrich, lent their complete collections of Utica, Frankfort and Lorraine fossils from New York. Professor H. F. Cleland sent us one of Emmons's types of Lorraine fossils. Raymond R. Hibbard made excellent slides of Lorraine bryozoans; Mr Erwin Pohl made photographs of specimens.

Professor Charles Schuchert lent the specimens of Proëtus from the Frankfort shale at Six Mile creek, in the Peabody Museum.

To Dr E. O. Hovey we are also greatly indebted for the liberal loan of types now in the American Museum of Natural History; and we should be ungrateful if we did not emphasize in this place how helpful in saving of laborious search in the literature, Bassler's Bibliographic Index of Ordovician and Silurian Fossils has been.

This work was finished in the spring of 1919. The later literature is therefore taken notice of only in footnotes and in the names of some fossils which have been meanwhile described.

Part 2, dealing with the fossils of the Utica and Lorraine formations will be published later.

RUDOLF RUEDEMANN

HISTORICAL SKETCH

A brief history of the Cincinnatian of New York, as far as its two lower divisions, the Utica and Frankfort shales, are concerned, has already been given by Ruedemann (1912, p. 7).[1]

The rocks of the Cincinnatian period in New York, comprising the Utica, Frankfort and Lorraine groups, were distinguished by the earliest geologists of the State as greywacke and slate. Thus J. O. Morse described in 1829 briefly the Great Greywacke region of the State of New York and Amos Eaton, in his Geological Textbook (1830) distinguished as " Second Greywacke " at the base of his " Lower Secondary, or Third Series," that belt of rocks which overlies the " metalliferous lime-rock " and " Birdseye-marble," in a general way corresponding to the Trenton group, and consists of " graywacke slate, grey rubble and millstone grit." He said that the belt extends from Georgia to Lake Ontario and underlies Utica and Rome, but includes in it Carboniferous rocks of Pennsylvania and the Catskill beds.[2]

Eaton paid no attention to the fossils but attempted to distinguish the formations merely by their mineralogic aspect. The result was a much confused system. At the same time, however, others began to study the fossil contents of the rocks.

Jacob Green (1832) described some of the most important trilobites of our Cincinnatian such as Triarthrus becki, Cryptolithus tesselatus and Isotelus stegops.

With the creation of the first New York State Geological Survey in 1836, a systematic, well-organized investigation, both as to the stratigraphic and paleontologic sides of our formation was inaugurated.

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[1] The dates after authors' names refer to the Bibliography, beginning on page 168.

[2] It is interesting to note that Eaton's " first graywacke," consisting of " graywacke slate," "millstone grit and grey rubble," is said to extend from Georgia to Canada and is cited from the region between Cohoes and Schenectady and Saratoga Lake. It underlies, according to him, the Calciferous sandrock (Beekmantown) and Trenton and is thus distinguished from the Cincinnatian belt of the Mohawk valley as an earlier belt of rocks. It corresponds, at least in its main part, to our Normanskill, Snake Hill and Schenectady beds, which indeed, are older than the Cincinnatian. This first greywacke rests on the "Argillite," the lowest formation of the "Transition or Second Series." The argillite comprises besides shales of the Normanskill, Canajoharie and other formations, the roofing slate of Hoosick and Chatham and thus happens also to contain the Cambrian beds. It is for this reason that, as Doctor Clarke states, Hall claimed in letters that Eaton was the real discoverer of the Taconic system.

While the annual reports of the geologists of that survey were only concerned with the economic products of the New York rocks, the final reports of Emmons (1842, p. 397) and Vanuxem (1843, p. 56) gave full accounts of the Cincinnatian rocks, which by common consent of the geologists of that survey had been named according to their most typical outcrops. Emmons described the *Utica slate* and *Lorraine shales;* while Vanuxem distinguished the *Utica slate* and the *Hudson River group,* under which term he comprised the *Frankfort slate and sandstone,* and *Pulaski shales* (also called *Salmon River shales* by Conrad in the reports).

Both authors also gave illustrations of some of the most important guide-fossils, a few of which had already been described in the preliminary reports by Conrad, the paleontologist of the survey, rather inadequately and without figures. Emmons, on the other hand, figured a number of Lorraine fossils without describing them, such as Trinucleus caractaci, Orthoceras aequalis, Orthis crispata.

The term "Hudson River" ("Hudson River slate group") was first used by Mather in the annual report for 1840 for the entire mass of shale in the Hudson river valley. This was believed by him to overlie the Utica shale, and the term "Hudson River group" was adopted by the geologists of the survey for the series of formations above the Utica and below the Oswego sandstone, it being assumed that the Utica shale continued through the Mohawk valley into the Hudson river valley and there was not separable from the other shales (Hall, 1843, p. 30). Emmons, however, dissented (1842, p. 5) and claimed that the Hudson River series is not equivalent to the series that overlies the Utica shale in northwestern New York. Since he further held that the exposures at Pulaski were incomplete, he substituted the name "Lorraine" (spelled *Loraine* by him) from the village of Lorraine, Jefferson county, N. Y., for the beds above the Utica in northwestern New York. He did not recognize the Frankfort as a distinct member and comprised under Lorraine all beds above his supposed Utica, which he defined as ending with the disappearance of Triarthrus becki.

Vanuxem distinguished the "Utica slate," "Frankfort slate and sandstone" and "Pulaski shale." The Utica slate was named from the city of Utica, where its type exposures are seen along Starch Factory creek. It rests on the Trenton limestone and is overlain by the Frankfort slate and sandstone. It enters his district, or the Upper Mohawk valley, from the Lower Mohawk valley and continues northward into the Black river valley. As its guide-fossils were named Triarthrus becki, Graptolites dentatus and the "Utica trocholite." The Frankfort slate and sandstone was named from the exposure along Moyer creek at the village of Frankfort. The Utica slate, which is a deep bluish black rock, somewhat calcareous, weathering into a brownish or dark chocolate color, was said to change by imperceptible gradation into the Frankfort slate, which is not calcareous, light bluish in color, assuming when exposed a dull dark gray, green or olive color, and intercalated with a coarse, impure, gray sandstone (Greywacke and rubblestone of Eaton). Utica slate and Frankfort slate and sandstone were considered coextensive and extending into the Hudson river valley. The Frankfort is a barren formation, having afforded "only one fossil from the eastern end of the Helderberg to Oneida county." In the Mohawk valley it is capped by the Oneida conglomerate, farther west by the Pulaski shale.

The Pulaski shale of Vanuxem was named after the village of Pulaski, Oswego county, where the shale is exposed along the Salmon river. It consists, according to Vanuxem, of bluish shale and dark gray colored sandstone, "the two more or less intermixed with each other;" and also containing limestone bands. As characteristic fossils were named Pterinea carinata, Cyrtolites ornatus and Pentacrinites hamptoni; as well as a whole series of Cypricardites (modiolaris, angustifrons, nasuta, ovata, curta), and Orthonota pholadis. The Pulaski shale makes its first appearance 2 miles to the south of Rome and thence extends north around the high plateau between the Black river valley and Lake Ontario.

Vanuxem (*op. cit.* p. 67) also described as a distinct unit the grey sandstone of Oswego, into which the Pulaski shale grades and which is here (see p. 138) united with the Lorraine under the Cincinnatian.

The paleontology of the Cincinnatian was placed on a firm basis by the work of James Hall in the first volume of his Palaeontology of New York (1847), who not only figured and more fully made known the fossils before briefly described by Conrad, but also well described and figured all other fossils from the Utica and "Hudson river groups" then accessible to him, among them a number of Cambrian forms and the graptolites of the Normanskill shale. After exclusion of these there still remain some eighty species, or one-third of all the forms here assigned to the Cincinnatian of New York, which were described and figured by Hall in volume 1. Hall also had recognized at that time the occurrence of a number of characteristic fossils of the "Hudson River group" in the West, notably in Ohio and Indiana.

In volume 3 of Palaeontology of New York (1852, p. 14), Hall extended the term "Hudson River group" to "all beds from the Trenton limestone to the Shawangunk conglomerate," a conception which was taken up by the textbooks[1] and came into general use.

Billings (1861) compared the graptolites of Europe and America and endeavored to show that the graptolite shales of the Normanskill near Albany were not in the upper part of the Lower Siluric, or Hudson River group, as Hall maintained, a contention which is now decided in Billings' favor.

In 1862, Hall (1862, p. 47, footnote) concluded from the results of the extended study by the Canadian geologists, especially Sir William Logan, (see Logan, 1863) that the strata referred to the Hudson River group in the valley of the Hudson belong to another epoch than those referred to the same epoch in western New York and the Mississippi valley.

He therefore dropped the use of the term "Hudson River group" for the western rocks, but 15 years later (1877, p. 259 ff.) he reviewed the evidence on which his conclusions were based and concluded that he had been in error.

Under the influence of Hall's withdrawal of the term " Hudson River group," Meek and Worthen proposed in 1865 the use of the name "Cincinnati" for the group. The term was adopted by the geologic surveys of Illinois and Ohio and came into general use in the West. Some geologists, however, preferred to use the term " Lorraine," as proposed by Emmons, on the ground of priority; and when in 1877 Hall stated that he had been led into error in considering the rocks in the valley of the Hudson as of Primordial age, or older than those of the Lorraine and Cincinnati sections, and that he thought the term "Hudson River group" should be used in geologic nomenclature, as it had specific value, many geologists returned to this term.

Logan, in his monumental Geology of Canada (Logan, 1863) furnished careful descriptions of the "Utica" and "Hudson River" formations in Canada, giving sections, a full account of their distribution and figures of the most important fossils. The Utica and Hudson River shales are described (p. 210) as passing out of the province of Quebec, ascending Lake Champlain and coming upon the Hudson river, thence turning to the valley of the Mohawk and finally reaching the shores of Lake Ontario. Graptolites of the type of those occurring at the Normanskill in New York (Graptolithus bicornis, G. ramosus) are referred to the Utica shale; the graptolite fauna, described by Hall from Point Levis, etc., is placed with the "Quebec group."

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[1] The first edition of Dana's Manual of Geology, which appeared in 1863, distinguished (p. 217) the "Hudson Period" as comprising (1) the Utica epoch, represented by the Utica shale; (2) "The Hudson river epoch, or that of the Hudson river shale and contemporaneous limestones." In later editions (see p. 489, the fourth edition, 1895) he united the " Utica and Hudson epochs " with the "Trenton epoch" under the "Trenton period."

The second Geological Survey of Ohio, under the directorship of Newberry, began in 1869 a thorough study of the geological structure and of the paleontology of the state. The fossils of the "Cincinnati group," which term was adopted for the "Blue limestone series" of the first survey, were described and figured, in volume 1, part 2 (1873) by Meek, and in volume 2, part 2 (1875) by Hall and Whitfield. Many of the fossils here recorded from the Lorraine of New York are found among those described by these authors. The stratigraphic work was later ably continued by Edward Orton, who (1888, p. 8) showed that the black Utica shale, which is 300 feet thick in the north of Ohio, gradually thins toward the south and may be represented by the 50 or 100 feet of black shale above the Trenton (Point Pleasant beds). Orton had already in 1873 (vol. 1, p. 372) proposed the name "Eden shale" for the middle division of the Cincinnati beds, the lower division being the River Quarry beds and the upper the Hill Quarry beds.

The paleontologic work of Meek, Hall and Whitfield for the survey on the Cincinnatian fossils was continued by Ulrich, who described the lamellibranchs of the Ordovician of Ohio in volume 7 (see Ulrich, 1893).

Whitfield (1877, p. 19) correlated the graptolite shales of the Normanskill with the Utica, citing as proof the occurrence of supposed Normanskill graptolites in the Utica shale of the neighborhood of Fort Plain, namely, Didymograptus serratulus, Dicranograptus ramosus, Climacograptus bicornis. The writer (1901, 1908) has shown that this view is based on the wrong identification of these graptolites. It had, however, an important influence in inducing other authors to refer a large part of these shales of the Hudson valley to the Utica shale.

Ulrich began in 1878 (Ulrich, 1879) the publication of his brilliant researches into the fauna of the Cincinnatian of the Ohio valley, which led to a complete revision of the work there carried on by Hall, Whitfield, Meek, James, Miller, Nicholson and others, and especially to a thorough knowledge of the bryozoans, lamellibranchs, gastropods and ostracods (see Ulrich, 1897) of the Cincinnatian period. A large percentage of the western species here recorded from our Cincinnatian rocks were first made known by Doctor Ulrich. His work is being successfully continued by Doctors Foerste, Cumings and Bassler.

Walcott in 1883 published two important papers on the Utica slate in the Trans. Albany Institute (see Walcott, 1883). In these he added a considerable number of new types: Cyathophycus reticulatus, C. subsphericus, Dendrograptus compactus, simplex and tenuiramosus, Graptolithus annectans etc. to the list of hitherto known Utica species. The geographic distribution of the Utica shale within and without New York was fully discussed and the Utica shale considered as comprising the black graptolite shales of the Hudson and Mohawk Valleys, (the graptolites of the Normanskill being held as marking the upper Utica). The Galena limestone, the Triarthrus beds of Cincinnati, the Orthis bed of Tennessee, the Thebes sandstone and the graptolite shales, in part, of Virginia, Tennessee and Alabama were correlated with the Utica shale, and the thickness of the latter, before greatly underestimated, was given as over 600 feet at the type section. The presence of passage beds between the Trenton limestone and Utica slate in the region of the type section was pointed out.

Beecher in 1883 (p. 78) published a list of fossils from the black shale near the old Dudley Observatory in Albany, referring the beds to the Utica epoch, and Ford (1885, p. 397) soon after recorded the discovery of a few fossils (Graptolithus pristis, G. mucronatus, Triarthrus becki and Lingula curta) in the slaty and arenaceous rocks in the vicinity of Schenectady, which on the strength of this evidence he also considered as of Utica age, while the preceding authors (Vanuxem) had referred them to the Frankfort slate, respectively Hudson river shale (Mather, Emmons).

Lapworth (1886, p. 167) studied the graptolite faunas of Canada and sought to determine their age by comparing them with the graptolite zones which he had distinguished in Great Britain. He recognized two main faunas, each divided into two subfaunas. He termed the fauna found at the Normanskill the Marsouin river or Coenograptus fauna and considered it rather of Trenton-Utica than

Utica-Hudson age, stating that in Great Britain it occurs in beds apparently homotaxial with the Chazy or lowest Trenton.

Ulrich, in 1888 published an important series of papers in the American Geologist in which a correlation of the Lower Silurian horizons of Tennessee and of the Ohio and Mississippi valleys with those of New York and Canada was carried out. The succession of faunas and horizons in the Cincinnatian beds was carefully worked out and extensive fossil lists were given, but no names were proposed for the horizons, although some later used by Nickles, were already suggested.

Walcott in 1890 (p. 335 f.) read a paper on "The Value of the Term Hudson River Group." In this he gave a history of the term and argued for the extension of the term "Hudson" to all beds between the Trenton limestone and Upper Silurian, on the ground of the extension of the Utica and Frankfort shales into the Hudson valley, then so generally accepted.

Walcott, in this paper, also gave a long list of fossils found in the Lorraine near Rome (*op. cit.* p. 347). This fauna largely corresponds to that of the Whetstone gulf formation north of Rome, listed in the present publication. There were further published the first section of the Lorraine, with faunal lists, and a statement as to the thickness of the Lorraine sandstone and shale (880 feet) and Utica (120 feet) in a well at Fultonville, Oswego county. The 1000 feet in northwestern New York correspond, according to a diagram, to about 3500 feet of rock in the Hudson valley. The following table of the members of the "Hudson" was given:

Hudson {
Hudson River shales and grits. Utica shale.
Frankfort shale.
Lorraine shale and sandstone.
Salmon River sandstone and shale.
Cincinnati shale and limestone.
Nashville shale.
Maquoketa shale.

In the discussion Professor Hall expressed his complete agreement with these views which fully represented the status of the Cincinnatian at that time.

Prosser (1890, p. 131) published in the same year gas-well sections in the upper Mohawk valley and central New York, which gave important information about the relative thicknesses of the members of the Cincinnatian about Utica and west of it.

Prosser and Cumings jointly (1895), and Prosser (1900) and Cumings (1900) separately published detailed sections of the shale formations of the lower Mohawk valley, showing the great thickness there of the supposed Utica and Frankfort shales, which on the Amsterdam quadrangle amounts to 950–1260 feet for the "Utica" and 1200 feet for the "Frankfort."

Ami (1892) published a paper on the Utica terrane in Canada, giving extensive fossil lists of the black shales which he considered as transitional from the Trenton to the Hudson river in their fossil contents. The so-called Utica or Hudson River shales of Quebec city, Cape Diamond, of the Marsouin river beds, of the Normanskill, or the " Coenograptus " shales in general, were stated not to occur anywhere in Canada where the Utica shales are found in their undisturbed condition and were referred to the " Quebec terrane."

In 1897, in the Palaeontology of Minnesota (vol. 3, pl. 1), Winchell and Ulrich published a full description of "the Hudson River or Cincinnati period," under which terms they included all rocks lying between the top of the Trenton and the base of the Upper Silurian. They urged the use of the name "Cincinnati" instead of "Hudson River" on the ground that the series at Cincinnati is more complete. They showed the period to begin at Cincinnati with the Utica and characteristic Utica fossils, as recognized by Hall as early as 1842. The remainder they divided into the Lorraine and Richmond groups, the latter name being proposed for a large series of strata not represented in the State of New York.

Ruedemann (1897) demonstrated that in the Utica shale of the Mohawk valley distinct evidence is found of marine currents following a northeast-southwesterly course.

Meanwhile the Paleontology of the Cincinnatian had been steadily furthered. Hall and Clarke in Paleontology of New York, volume 8, furnished accurate generic determinations and figures of the more important of Cincinnatian brachiopods (Hall and Clarke, 1892–94); Beecher (1893–96) described the appendages of Triarthrus becki and Cryptolithus tesselatus; Ruedemann (1895), the development and structure of several graptolites from the Utica and Canajoharie beds, as well as a sessile Conularia (1897). The Minnesota Report, volume 3 (1897), contained a series of important monographs by eminent specialists describing western Ordovician fossils, some of which have also been met with in our Lorraine; namely, Sponges, Graptolites and Corals, by N. H. Winchell and Charles Schuchert; Brachiopoda by the same authors; Bryozoa, Lamellibranchiata and Ostracoda by E. O. Ulrich; Gastropoda by E. O. Ulrich and W. H. Scofield; Cephalopoda and Trilobites by John M. Clarke.

In 1899 Clarke and Schuchert published a new Nomenclature of the New York Series of Geologic Formations in which the old term "Champlainic," used by the geologists of the first survey was revived for the Ordovician or Lower Silurian, and this Champlainic divided into three periods or groups, namely, the Canadian, Mohawkian and Cincinnatian; the latter being subdivided into the Utica shale, Lorraine beds and Richmond beds. Regarding the term Hudson River beds, it was stated:

> It is becoming increasingly evident that the great mass of shale in the Mohawk and Hudson river valleys which was designated at an early date by this term is resolvable into horizons extending from the middle Trenton to and including Lorraine beds. At present it seems unlikely that, when this determination of horizons has been carried through the series, any part will remain to which the original term can be applied by virtue of its distinctive fauna, though it may still serve to designate a facies of the formations mentioned.

This nomenclature was retained in the Classification of the New York Series of Geologic Formations, published in 1903 by Doctor Clarke (Clarke, 1903). The Frankfort, Pulaski and Salmon river shales were here considered "as early terms applied to the local development of these beds in central New York."

A few notes on the Frankfort shale sections along Moyer creek near Frankfort (the type section) and Ferguson creek near Utica were published by Theodore G. White in 1899 and the presence of Triarthrus becki, a small Orthis, a small Orthoceras and graptolites was recorded in these sections.

In 1901 Ruedemann correlated the graptolite shales at Normanskill (hitherto considered as of Utica age) as "Normanskill shale" with the lower Trenton and argued on this account for the suppression of the term "Hudson River group." He also pointed there to the decrease of the Trenton limestone eastward in the Mohawk valley and the rapid increase of the "Utica" shale in the same direction. In the following years the same author also showed the presence of graptolite zones ranging from the top of the Cambrian through the Beekmantown and Chazy epochs to the Trenton and Utica in the Hudson river shales (see Ruedemann, 1902 p. 546; 1903, p. 934). A broad belt of shales on the west side of the Hudson overlying the middle Trenton shales and Normanskill shales was still referred to the Utica shale; and the shales at Cohoes and to the west of the Utica belt were in accordance with the views of Hall, Vanuxem, Prosser and Cumings, correlated with the Frankfort division of the Lorraine group, mainly on the ground of a series of small lamellibranchs obtained about Cohoes, and of the supposed upper Utica aspect of the Dudley Observatory faunule.

Nickles (1902, p. 49) in his Geology of Cincinnati, gave a history of the terminology of the Cincinnati section and supplied names derived from both the type locality and the most characteristic fossil to each of the horizons distinguished in the Cincinnatian of that region. He divided the Cincinnatian into (1) the Utica group, rejecting Orton's name "Eden" (Orton, 1873, p. 372) for the lower division on the ground that the latter is of the same age as the Utica of New York; (2) the Lorraine group; and (3) the Richmond group. The "Utica group" which is said to be about 260 feet thick was divided into (1) lower Utica or Aspidopora newberryi beds; (2) middle Utica or Batostoma jamesi beds; and (3) upper Utica or Dekayella ulrichi beds.

The Lorraine was divided in descending order as follows: (6) Warren or Homotrypa bassleri beds. (5) Mount Auburn or Platystrophia lynx beds. (4) Corryville or Chiloporella nicholsoni beds. (3) Bellevue or Monticulipora molesta beds. (2) Fairmount or Dekayia aspera beds. (1) Mount Hope or Amplexopora septosa beds.

The Richmond group was likewise divided into zones which however, do not concern us here. Long lists of fossils of the different zones testify to the wonderful richness of the Cincinnatian faunas at Cincinnati, which has been productive of so many excellent geologists.

Nickles's Utica corresponds to the Eden as it is understood today, his lower Utica to the Fulton and Economy members, his middle Utica to the Southgate and his upper Utica to the McMicken.

In 1902 Palaeozoic Seas and Barriers in Eastern North America was published by E. O. Ulrich and Charles Schuchert (Ulrich and Schuchert, 1902, p. 633). This paper helped greatly in the elaboration of the complex shale problems by pointing to the existence of separate troughs or channels in the seas that once occupied the shale region (the Chazy and Levis troughs) of New York and to the draining of these channels independently of each other.

Weller (1903, p. 49) studied the "Hudson River slates" of New Jersey and found a Normanskill fauna near the base which was correlated with the middle Trenton of New York. The remainder of the Hudson River shale was considered as possibly the time-equivalent of the Utica and Lorraine of New York.

Cushing (1905) on the Little Falls sheet mapped the 100 feet of passage beds between the Trenton and "Utica" as a separate unit, and in a later communication to Professor Miller (see Miller, 1909, p. 21), he proposed the term "Dolgeville shale" for these passage beds, considering them "as a shaly eastern representative of the upper Trenton limestone of the type section." These beds were found by Miller to be absent on the Remsen quadrangle which adjoins the Little Falls quadrangle on the west.

The same author (Cushing, 1905, p. 382) in his Geology of the Northern Adirondack Region, discussed the Utica and Lorraine formations (including the Frankfort) in their lithologic aspects and former distribution around and upon the Adirondack plateau. He brought out (*op. cit.* p. 384), through well-sections, the important fact that, while the Trenton thickens rapidly northward from Utica, and more gradually westward, the Utica thins correspondingly northwest and westward, and he saw therein a strong indication of the contemporaneity of the upper Trenton and lower Utica in the contrasted districts. In regard to the Lorraine, he adopted the view expressed by Walcott (1890) that there existed a shallowing of the sea in the Utica meridian early in Lorraine time.

Ruedemann, in the Graptolites of New York, part 2 (1908, p. 29) distinguished several subzones with graptolite faunules in the Hudson valley as older than the Utica, and younger than the Normanskill shale. These were brought together under the "Magog shale" (zone of Diplograptus amplexicaulis) and placed in the Trenton. Lists of the graptolite faunas of the different Cincinnatian horizons were given and the graptolites were described and figured. The beds, however, later separated as Canajoharie shale are still retained in the Utica (zone of Glossograptus quadrimucronatus and Climacograptus typicalis) and the beds with Frankfort and Lorraine facies in the Hudson and lower Mohawk valleys are not yet separated from the Lorraine.

Cumings in 1908 in The Stratigraphy and Paleontology of the Ordovician Rocks of Indiana published together with detailed sections of the Cincinnatian in Indiana, the original descriptions and figures of the characteristic fossils of the Cincinnatian, thereby furnishing a most helpful aid to the student of the Cincinnatian faunas.

Miller in 1909 in the Geology of the Remsen Quadrangle briefly discussed the character of the Utica shale and Frankfort shale (termed Lorraine beds) in the Trenton Falls district, and in the following year he described the quadrangle adjoining to the north, again furnishing data as to the decreasing thickness of the Utica and Lorraine (Frankfort) in northward direction.

In a paper by Grabau on "The Physical and Faunal Evolution of North America during Ordovicic, Siluric and early Devonic Time" (1909), the Utica and Trenton are considered as synchronous, the Trenton being "the limestone phase of a series which elsewhere is in part or mostly represented by Utica shale." The Eden was held to be "in part equivalent to the Frankfort shales, though the occurrence of Climacograptus typicalis in the Eden strata would favor its former correlation with the Utica." The Maysville was stated to represent "later Lorraine as developed in New York, though the fauna, being that of a calcareous facies, is markedly different."

On account of the intimate faunal relationship between the Utica and the Eden and Maysville, on one hand, and the Utica and Trenton, on the other, Grabau placed the Trenton together with the Cincinnati series into the Upper Ordovician.

To the south of New York, in New Jersey, Pennsylvania and West Virginia, the shales which formerly were termed "Utica and Hudson River slates" are now known as Martinsburg shale. The Martinsburg shale of the Mercersburg-Chambersburg quadrangle in Pennsylvania was described by Stose (1909) and fossil lists were given by Ulrich (p. 10). The lowest shale fauna is considered as indicating an age corresponding to that of the lower to middle Trenton of New York, and the highest as comprising species characterizing the Eden shale.

Bassler, in his work on the Cement Resources of Virginia (1909) the federal survey's part of which was done under the official direction of Doctor Ulrich, divided the Martinsburg shale in three divisions, namely, upper Trenton shale, Utica shale and Eden shale, representing the shaly Ordovician deposits of the Appalachian trough. The Martinsburg is continuous from Virginia through Pennsylvania and New Jersey with the shale belt of New York, and this division of the shales has a direct bearing on that of the shale in the New York part of the Appalachian trough, represented by the shales in the Hudson river valley.

Schuchert (1910), in his Paleogeography of North America, referred the Utica of New York as the zone of the Mastigograptus fauna to the top of his Ordovician period. As characterizing the shale facies of the Trenton in the Atlantic province were cited the Climacograptus caudatus, Corynoides curtus and Magog graptolite zones, while the horizon of the Normanskill shale was correlated with the Black River of New York and Kimmswick of Illinois and Missouri. The Frankfort was correlated with the Edenian and placed in the Cincinnatian period, the Ordovician period being considered as closed by the Utica emergency. The Lorraine was correlated in part with the Edenian and in part with the two lowest zones (Mount Hope zone, Fairmount zone) of the Maysvillian. The Edenian, Maysvillian and Richmondian were united in the Cincinnatian system. Paleogeographic maps of North America in the late Trenton, Utica and Lorraine stages by Ulrich and Schuchert were given, to which we will have occasion to refer.

A new light was shed on many problems, here involved, in the Revision of the Paleozoic System by Ulrich (1911). We have here especially in mind Ulrich's theories of a multiplicity of shallow continental seas and of frequent and periodic migrations of faunas from their permanent oceanic habitats into these inland seas; his views on many questions here coming up, such as that of the graptolite shales and black shales in general; and finally his comprehensive correlations, brought out in the plates 27–29. We shall have frequent occasion, in this publication to return to Ulrich's and Schuchert's above-cited epochal works.

Ulrich recognized the Cincinnatian as the fourth division of the Ordovician. He subdivided it into the Eden and Maysville groups, the former again into the Utica and Frankfort, the latter into the Fairview and McMillan. The Richmond was transferred to the Silurian. The Lorraine, which name was only used as a local term, was divided into the Frankfort shale and Pulaski formation, the latter being correlated with the Fairview. The Oswego sandstone was correlated with the McMillan and thus separated from the Silurian and placed at the top of our Ordovician.

Bailey Willis (1912), in his Index to the Stratigraphy of North America, gathered all information extant in print to that date and thus created not only an extremely valuable and useful book but also a datum plane in stratigraphic history. He published (p. 198 ff) manuscript contributions from Ami, giving the geologic formations at Ottawa, Montreal and Quebec, with fossil lists. The Utica and Lorraine were reported in those tables as composing the Upper Ordovician. In New York (p. 184) the Upper Champlainic or Lower Siluric consisted of the Utica and Lorraine shale. The latter had as subdivisions, the Pulaski shale, Frankfort shale and Salmon River shale. The Frankfort shale was considered as continuing to eastern New York.

Ruedemann published in 1912 a bulletin on The Lower Siluric Shales of the Mohawk Valley. In this paper, it was shown on stratigraphic and faunal evidence that the black shales of the lower Mohawk valley, hitherto referred to the Utica, are of lower Trenton age. They were distinguished as Canajoharie shale; the rocks of Frankfort and Lorraine aspect in the same region were also proven to be of Trenton (and possibly in part Utica age) and termed the Schenectady beds. A new formation with a distinctive faunule of its own of the age of the Southgate member of the Eden was recognized in the Indian Ladder beds, which are of the age of the Frankfort shale, in part at least, but not connected with it in the Mohawk section. Both the Canajoharie shale and Schenectady beds pass along the western side of the Hudson valley. Farther east, still another formation of shale and sandstones, also with a large fauna, was recognized as of Trenton age, but deposited in a different basin, and separated as the Snake Hill beds. A number of graptolite zones were recognized in the Canajoharie shale.

These new formations were fully described as to their lithologic aspect, thickness, and distribution in the upper Hudson valley, in the Geology of Saratoga Springs by Cushing and Ruedemann (1914, p. 48).

A new edition of the Handbook on the Classification of the Geologic formations of the State of New York was published by Hartnagel (1912). In this all formation names of New York were credited to their authors and the dates of their first mention were given. The Cincinnatian group which follows the Mohawkian group, was divided into the Utica shale, Frankfort shale and Pulaski shale.

A large section of the Cincinnati Series, at Tanners Creek, in Indiana, was published by Cumings and Galloway (1913).

Ulrich (1914, p. 593), in a paper on the Ordovician-Silurian boundary read before the International Geological Congress in Toronto, presented his arguments against the acceptance of a Cincinnatian system as proposed by Schuchert, that is, beginning above the Utica and including the Richmond; and incidentally discussed the extension and oceanic connections of the Utica, Eden and Maysville seas, illustrating his views by paleogeographic maps of the Eden, Maysville (in the Fairview and McMillan stages) and Richmond seas.

The most important chapter, however, in this paper, for our present investigation is that on the Oswego sandstone, in which the section, with fossil lists, at Salmon river falls was given and the Oswego sandstone was correlated with the MacMillan of the Cincinnatian, thus being removed from the base of the Silurian and placed at the top of the Ordovician.

Incidentally, at the International Geological Congress, there also appeared a series of valuable guide books, some of which contain chapters of distinct value for our inquiry. One of these is the Ordovician of Montreal and Ottawa by Raymond (1913, p. 137), the other is The Geology of the Clay Cliffs, Cape Smyth, Manitoulin Island by Foerste (1913, p. 76). Doctor Raymond divided the former Utica into the Collingwood, a sort of transition between the Trenton and Utica, 25 to 50 feet thick and containing Ogygites canadensis, Triarthrus becki, Dalmanella emacerata, Schizambon canadensis etc., and the true Utica, 200–300 feet thick, with Climacograptus typicalis, Diplograptus pristis, Triarthrus becki, T. spinosus and T. glaber. The presence of both the Lorraine and Richmond, the latter with Catazyga headi, were noted. Doctor Foerste listed the following formations from the Lake Huron area: Collingwood (Utica absent), Eden, Lorraine, lower, middle and upper Richmond. Small lists of the most frequent fossils were given in both papers.

The year 1914 brought a most important paleontologic publication on the Lorraine faunas in Foerste's Notes on the Lorraine Faunas of New York and the Province of Quebec. In this paper the following Lorraine fossils of New York were fully discussed and some of the types were reproduced in photographs, namely, Lingula rectilateralis Emmons, Pholidops subtruncata Hall, Glyptorthis crispata (Emmons), Dalmanella centrilineata (Hall), Rafinesquina nasuta (Conrad), Rafinesquina mucronata Foerste, Catazyga erratica (Hall), Caritodens demissa (Conrad), Byssonychia radiata (Hall), Colpomya faba-pusilla (Foerste), Pholadomorpha pholadiformis (Hall), Modiolopsis modiolaris (Conrad), Orthodesma nasutum (Conrad), Orthodesma pulaskiense Foerste, Cymatonota pholadis (Conrad), Ischyrodonta curta (Conrad), Clidophorus planulatus (Conrad), Ctenodonta lorrainensis Foerste, Lyrodesma poststriatum (Emmons) Hall, Archinacella pulaskiensis Foerste, Ruedemannia abbreviata (Hall), Cornulites sp., Cryptolithus tesselatus Green, Calymene conradi Emmons, Byssonychia carinata Goldfuss.

In the introductory notes to this paper, the author stated the conclusions arrived at in a joint trip with Doctor Ulrich to the exposures at Pulaski and to the uppermost Lorraine and Oswego sandstone sections at the Salmon river falls and Bennett Bridge, Oswego county, New York. The discovery at Bennett Bridge of forms which suggest middle Maysville (lower Bellevue) affinities was announced and as a preliminary conclusion it was suggested that the upper or Pulaski part of the Lorraine fauna is younger than the Eden at Cincinnati and older than the upper or McMillan division of the Maysville, while the lower, shaly part of the Lorraine, from information from Doctor Ulrich, may be correlated with the Eden. The probable gradual change of the Lorraine facies into the Cincinnatian facies along the northern shores of Lake Ontario and the possible influence of the Frontenac axis were mentioned.

In 1915 Bassler's Bibliographic Index of American Ordovician and Silurian Fossils was published. This eminently useful work contains a surprising amount of new information buried in the index, in new generic determinations, suggested synonymies, and in the faunal lists of the formations and correlation tables, given at the end of volume 2.

Schuchert, in his excellent Historical Geology (1915, p. 629) divided the Ordovician into the Lower Ordovician or Canadian, the Middle Ordovician or Champlainian and the Upper Ordovician or Cincinnatian. The Collingwood was referred to the Middle Ordovician, the Eden and Utica, Maysville and Lorraine, Richmond and Gamache were placed under the Upper Ordovician. The Cincinnatian paleogeography was illustrated by a chart, giving the outlines of the Utica-Eden and Maysville-Lorraine epicontinental seas.

The year 1916 brought two most important papers bearing on the Cincinnatian problems, by Foerste and Raymond.

Foerste published a memoir on the Upper Ordovician Formations in Ontario and Quebec, in chapter 1 of which a brief review of the Cincinnatian of New York was given, to be noted in another part of this paper. The presence in Canada not only of the Eden and Maysville, but also of the Waynesville, Whitewater and Saluda divisions (Queenston shales) of the Richmond was there demonstrated.

Raymond (1916) instituted a correlation of the Ordovician strata of the Baltic basin with those of eastern North America. He correlated with the zone of Dicranograptus clingani (the middle Dicellograptus beds of Sweden), which in Scandinavia follows upon the Nemagraptus gracilis zone (corresponding to our Normanskill shale), the Canajoharie, Snake Hill and Cumberland Head shales; with the Pleurograptus linearis zone our typical Utica at Holland Patent and the Fulton shale of the Eden. The Schenectady formation he considered equivalent to the Utica and, probably, the Frankfort. The Canadian Trenton was divided into four divisions, namely, the Rockland formation, the Hull formation, the "Prasopora" beds or true Trenton and the Picton formation, upon which rest the black shales, which were divided into the Collingwood and Gloucester formations.

The origin of the black graptolite shales has been the subject of intermittent discussion, by Hall (1865), Jaekel (1889), Wiman (1895), Lapworth and Walther (1897), Ruedemann (1904, 1908, 1911), Ulrich (1911), Hundt (1911), Twenhofel (1915), Grabau and O'Connell (1917), and others. The problem is here taken up, as far as the Utica shale is concerned, on p. 73.

A number of papers bearing on subjects discussed in this monograph came to hand after the manuscript had been finished (April 1919) and was waiting for the printer. They have in some cases afforded valuable additional data on Cincinnatian stratigraphy or faunas, and these have been incorporated as far as possible.

The most important of these is Bassler's Cambrian and Ordovician of Maryland (1919), in which the Martinsburg shale of Maryland and Southern Pennsylvania, the southern continuation of our "Hudson River shale" belt of New York, was comprehensively treated and a large series of paleogeographic maps of Ordovician time in North America by Ulrich were published. Bassler's subdivision of the Martinsburg shale will be fully noted in another place. Suffice it to say here that he recognized in the 2500 feet of shale a Trenton and Utica division, an Eden division, a lower and an upper Maysville division (the latter the Oswego sandstone).

Ruedemann has published a list of all the graptolite zones of the Ordovician shale belt of New York (N. Y. State Mus. Bul. 227–28, 1919, p. 166) in which twenty graptolite zones are distinguished; including those of the Utica shale, here described.

UTICA AND FRANKFORT FORMATIONS

SECTIONS

Beginning near the Hudson river there extends through the Mohawk valley to Utica, and thence northward along the Black river valley to its end near Watertown, a belt of three contiguous lithologic units, namely, a limestone formation, overlain by a black shale formation, that in its turn is followed by a thick mass of shales and sandstones. The limestone formation, which is thinnest in the lower Mohawk valley (only about 24 feet) thickens rapidly until it reaches 300 feet near Trenton Falls and 475 feet at Atwater brook. Northward from this place toward the outlet of Lake Ontario, the thickness decreases somewhat gradually to about one-half the maximum. It is known as the "Trenton limestone." The black shale formation begins with about a thousand or more feet at the mouth of the Mohawk, amounts to some 700 feet about Utica and dwindles to about 70 feet at its northernmost exposure at Copenhagen, southeast of Watertown. This black shale formation is currently known as the "Utica shale."

It is overlain by a mass of more than 2000 feet of grayish shale with many sandstone intercalations and some thin black bands in the lower Mohawk valley. This thick formation decreases to about 300 feet about Utica, where it consists mainly of shale with some sandstone beds near the top. Toward the north this belt again thickens to 600 feet about its northern terminus at Lorraine. Its lower more shaly portion is known as "Frankfort shale," and the upper terrane consisting of shales and sandstones as "Lorraine beds."

The author's work in the Hudson valley showed that the great mass of so-called Hudson River shales comprises beds ranging from the lowest Ordovician to beds of Trenton age. It was later extended to the shales of the lower Mohawk valley. It was proven, in a former publication (Ruedemann, 1912) that the black graptolite shale of the lower Mohawk valley is older than the typical Utica shale and of early Trenton age. This early shale formation was termed the " Canajoharie shale," and four zones were distinguished in it:

4 Zone of Climacograptus spiniferus, Diplograptus vespertinus, Lasiograptus eucharis

3 Zone of Lasiograptus eucharis

2 Zone of Glossograptus quadrimucronatus cornutus, Corynoides calicularis
1 Zone of Diplograptus amplexicaulis, Corynoides calicularis

It was observed that only the two upper zones (3 and 4) extend westward to and beyond Dolgeville. Here they rest upon Trenton limestone, the third shale zone being connected with the Trenton by intercalation and gradation of limestone into shale (Dolgeville beds of Cushing).

The true Frankfort beds were not observed in the lower Mohawk valley; in their place there appear at the Indian Ladder shales with thin limestone and some sandstone intercalations, that contain a distinct fauna, characteristic of the lower third of the Southgate shale of the Eden group at Cincinnati. This formation has been termed the " Indian Ladder beds."

Between the Canajoharie shale and the Indian Ladder beds the great mass of the " Schenectady beds " is found in the lower Mohawk valley, a terrane consisting of shales, sandstones and grits, and quite fossiliferous in certain portions. A fairly large fauna, of thirty-nine species, the most striking element of which are eurypterids, was obtained in this formation. Besides these it contains Canajoharie, Utica and Trenton species, and it was thought that these indicate a Trenton age for the shale. The conclusion of the Trenton age, for a part at least of the 2000 feet of Schenectady beds, is corroborated by its position on the Canajoharie shale, which is of lower Trenton age and which itself rests on Glens Falls limestone, the Trenton limestone representative of the lower Mohawk valley that is older than any part of the Trenton exposed at Trenton Falls. On the other hand, the Schenectady beds are followed by the Indian Ladder beds of Eden age, or beds of an age younger than the Utica. Providing there is no hiatus between the Schenectady beds and the Indian Ladder beds corresponding to the Utica shale, it is to be inferred that the upper part at least of the Schenectady is of Utica age, although the fauna does not give any support to this view. Indeed, Doctor Raymond has lately (1916, p. 250) suggested that the Schenectady beds are of Utica and probably also of Frankfort age. This problem can be discussed more advantageously after description of the Utica horizons.

Toward the west this thick terrane of gray shales and sandstones dwindles to the few hundred feet of Frankfort shale at Frankfort and Utica, which is directly followed by the Oneida conglomerate.

But west from Utica and Rome the Lorraine formation of like lithologic appearance with the Schenectady beds, appears quite abruptly and thickens very rapidly westward and northward.

The work begun in the lower Mohawk valley on the black graptolite shale belts and the overlying gray shales with sandstone, has been continued westward past the typical region of the Utica shale and northward to Lorraine and the neighborhood of the St Lawrence river. We were thereby enabled to distinguish four well-marked graptolite zones in the typical Utica shale, and another one in the northern continuation of the black shale, and still another in the Frankfort shale; and likewise a series of faunal zones in the Lorraine formation. To describe these zones in their faunal aspect and geographic extension is the purpose of this publication.

Utica Shale

Sections East of Utica

1 Otsquago and Loyal creeks near Fort Plain, N. Y. The first good Utica section was found near Fort Plain only 5 miles west of Canajoharie. The latter place furnished the type section for the Canajoharie shale, but failed to afford any exposures of the typical Utica, the upper portions of the tributaries of the Mohawk having not yet eroded through the drift.

The first outcrop at the old mill on Otsquago creek, just above the village, contains

Diplograptus vespertinus Rued. cc
Lasiograptus eucharis Hall c
Leptobolus insignis Hall cc
Lingula curta Conrad r
Geisonoceras tenuistriatum (Hall) c
Primitia sp.
Ulrichia bivertex Ulrich c
Bythocypris cylindrica (Hall) c

The fossils indicate that we have here the closing stage of the Canajoharie formation.

Outcrops fail until 190 feet above this Canajoharie shale, when lower Utica shale is indicated by:

Climacograptus typicalis Hall cc
Glossograptus quadrimucronatus approximatus Rued. c
Lasiograptus eucharis (Hall) c
Leptobolus insignis (Hall) c
Triarthrus eatoni (Hall) cc

Ninety-five feet above this station there were collected:

Glossograptus quadrimucronatus approximatus Rued. c
Triarthrus eatoni (Hall) cc
Calymmene sp. c
Geisonoceras tenuistriatum (Hall) c

Two hundred five feet above, under the bridge leading over Loyal creek, there occur:

Climacograptus typicalis Hall cc
Geisonoceras tenuistriatum (Hall)

Two feet above this bridge, there begins in Loyal creek, a northern tributary of Otsquago creek, near Starkville, a very marked zone, containing

Dicranograptus nicholsoni Hopkinson cc
Glossograptus quadrimucronatus approximatus Rued. c
Climacograptus typicalis Hall cc
Schizocrania filosa Hall r
Leptobolus insignis Hall c
Triarthrus eatoni (Hall) cc

This zone, in which Dicranograptus nicholsoni is everywhere the dominant fossil can be traced through 135 feet, that is, to the end of the section, about 150 yards above the second cascade. Toward the top of the exposure Dicranograptus nicholsoni becomes rare, according to Mr Hartnagel, who accompanied me over this section and kindly collected the material from the first cascade upward.

Two and one-half miles southwest of the end of the section, the transitional beds from the Utica shale to the Frankfort shale are found along Otsquago creek, just above Starkville. Like the end of the section on Loyal creek, this outcrop is also on the 700-foot contour, and since the dip of the rock is about 100 feet in 1 mile in that direction, some 250 feet of rock may be included in the upper Utica shale above the Dicellograptus nicholsoni zone. Owing to the southwest dip of the rocks, these upper beds are exposed in the lower reaches of the southern affluents of the Mohawk to the west of Otsquago creek. They are best seen along

Fulmer creek, south of the village of Mohawk. The first outcrop occurs at the southern outskirts of the village along the creek. Here are found:

Climacograptus typicalis Hall cc
Climacograptus pygmaeus *nov.* r (larger form)
Lasiograptus eucharis (Hall) r
Leptobolus insignis Hall c
Orthoceras r

Twenty-five feet higher up, in like compact black shale, occur

Climacograptus pygmaeus nov. cc
Glossograptus quadrimucronatus timidus Rued. c
Leptograptus insignis Hall c
Triarthrus eatoni (Hall) c (large form)

The faunule characterized by Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus could thence be traced along the road and creek in numerous outcrops through about 40 feet of rock, after which Climacograptus pygmaeus became the sole graptolite noticed as far as and beyond the transition beds to the Frankfort shale, about 86 feet above the base of the section. At Day's Rock, 125 feet above the base the typical barren Frankfort shale is seen.

This uppermost zone of the Utica shale is characterized by the abundance of Climacograptus pygmaeus and the presence of Glossograptus quadrimucronatus timidus, as well as by the absence, or at least rarity, of the common Utica graptolites, Climacograptus typicalis, Lasiograptus eucharis and Glossograptus quadrimucronatus approximatus.

Since the first outcrop on Fulmer creek, that with Climacograptus typicalis and Lasiograptus eucharis, is probably still to be reckoned with the preceding zone; the whole thickness of the zone with Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus may here amount to no more than 100 feet.

In the deep ravine of Spoon creek 2 miles east of Fulmer creek, a splendid section of the transition beds from the Utica to the Frankfort beds and of the latter is exposed. This was visited jointly by C. A. Hartnagel and the writer. Here also Climacograptus pygmaeus was the only graptolite obtained in the transition beds, which besides furnished only Leptobolus insignis and a closely annulated form of Orthoceras.

Nowadaga–Ohisa creek section. The most complete section through the Utica shale, observed by the writer is that along Nowadaga creek and its upper part known as Ohisa creek. This section which was studied jointly by C. A. Hartnagel and the writer, begins a half mile above the station of Indian Castle of the West Shore Railroad and runs roughly parallel to the Otsquago creek section and about 5 miles northwest of the latter. It is about 7 miles long and leads in practically continuous outcrops from the Canajoharie beds into the Frankfort shale, thus furnishing the only continuous Utica section known to the writer where both the top and the base of the Utica formation are exposed.

Station 1. The first exposure is found at practically the Mohawk river level, at about 360 feet. There are exposed black shales alternating with more or less argillaceous black, blocky limestone. These are the Dolgeville beds of Cushing and the outcrop has been mapped as such by that author on the Little Falls quadrangle. (1905). The shale contains:

Climacograptus spiniferus Rued.
Glossograptus quadrimucronatus (Hall) *mut.*
Lingula curta Conrad
Leptobolus insignis Hall
Schizocrania filosa Hall
Dalmanella testudinaria (Dalman)
Triarthrus eatoni (Hall)
Isotelus gigas Dekay
Ulrichia bivertex (Ulrich)
Endoceras sp.

This fauna is by the presence of Climacograptus spiniferus and Ulrichia bivertex shown to belong still to the Canajoharie formation.

Station 2. Another fossiliferous outcrop is exposed at the first bridge, about 40 feet above the first station by aneroid measurement and about 90 feet above the same in the section when the dip is taken in account.[1]

The rock is a black shale with some thin limestone bands. Thin layers of soft mud-shale proved to be filled with ostracods and Leptobolus, and some rock-surfaces are covered with graptolites. The following fossils were collected in this locality:

Dicranograptus nicholsoni Hopkinson
Climacograptus spiniferus Rued.
Lasiograptus eucharis (Hall)
Leptobolus insignis Hall
Plectambonites sericeus Sowerby (fragments)
Dalmanella rogata (Sardeson)
Endoceras sp.
Primitiella unicornis (Ulrich)
Primitia, 2 indet. species
Ulrichia bivertex (Ulrich)
Bythocypris cylindrica (Hall)
Aparchites minutissimus var. trentonensis Ulrich
Triarthrus becki Green
Ceraurus sp. fragments.
Odontopleura cf. crosota (Locke)
Lepidocoleus jamesi (Hall & Whitfield).

This fauna is still that of the Canajoharie shale.

Station 3. This comprises the black, hard, somewhat calcareous mud-shales of typical Utica appearance that follow directly above the Canajoharie and extend along the creek to the neighborhood of an old mill or through about 200 feet (100 feet rise by aneroid and 100 feet through the dip). These beds contain the typical Utica fauna. There were found successively beds with multitudes of

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[1] Cushing (*op. cit.*) found that the average dip of the sedimentary rocks in the Little Falls quadrangle amounts to a little more than 100 feet to the mile in southwest direction.

Lasiograptus eucharis and with Geisonoceras tenuistriatum and abundant Triarthrus eatoni, then beds filled with large specimens of Glossograptus quadrimucronatus approximatus besides the Geisonoceras; above these Climacograptus typicalis was the dominant fossil; then again Glossograptus quadrimucronatus approximatus with Geisonoceras tenuistriatum and Triarthrus eatoni. Above the third bridge Triarthrus is very noticeable in the black shale by the large size of the specimens and Climacograptus typicalis, is by far the most abundant graptolite, a few specimens of Glossogr. quadrimucronatus approximatus also being found.

The faunule of this station comprising the lowest Utica zone consists of:

Climacograptus typicalis Hall cc
Glossograptus quadrimucronatus approximatus Rued. cc
Lasiograptus eucharis (Hall) cc
Leptobolus insignis Hall c
Pterinea insueta Hall rr (one specimen found)
Geisonoceras tenuistriatum (Hall) c
Triarthrus eatoni (Hall) c

Station 4. The faunal associations so characteristic of the lower Utica, the graptolites, Lasiograptus eucharis, Glossograptus quadrimucronatus approximatus and Climacograptus typicalis and the small Geisonoceras and Triarthrus eatoni are abruptly followed by the black shales, in which Dicellograptus nicholsoni is by far the dominant fossil.

This zone extends to just below the Newville mill or through about 170 feet (70 feet by aneroid and 100 feet through the dip of the rocks). It contains in the lower part:

Dicranograptus nicholsoni Hopkinson cc
Climacograptus typicalis Hall c
Glossograptus quadrimucronatus approximatus Rued. r
Leptobolus insignis Hall r
Triarthrus eatoni (Hall) r

In the upper part, just below Newville there occur:

Leptograptus annectans Walcott r
Dicranograptus nicholsoni Hopkinson cc
Lasiograptus eucharis (Hall) c
Triarthrus eatoni (Hall)

Station 5. Directly above Newville a complete change in the faunal aspect of the Utica beds is observed. Here are found in black shales:

Cyathodictya pyriformis Ruedemann r
Corynoides ultimus Ruedemann cc
Climacograptus pygmaeus Ruedemann cc
C. typicalis Hall c
Glossograptus quadrimucronatus timidus Ruedemann c
Leptobolus insignis Hall c
Triarthrus eatoni (Hall)

This zone is characterized by the graptolites Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus. The Corynoides ultimus appears only in a thin zone in a surprising manner, long after the genus was thought to be extinct. The upper boundary of this upper Utica zone with the Frankfort zone is indistinct in this continuous section for the reason that the fossils gradually disappear and the black Utica shale changes by very slow gradation into the overlying gray Frankfort shale. About 1½ miles above Newville and 200 feet above the base of the third Utica zone the sandstone beds of the Frankfort appear and the rock has become typical Frankfort shale.

Summary of sections east of Utica. The Otsquago and Nowadaga-Ohisa creek sections are the only complete sections of the Utica shale that we have observed in the Mohawk valley. As Utica shale we define here all the black shale between the top of the Canajoharie shale (of Trenton age) and the Frankfort shale, with the qualification: in the Mohawk basin; for it will be seen in following chapters that another black shale formation of different derivation and maritime connection is met with in the Black river valley.

There are three major graptolite zones developed in these sections. These are in descending order:

3 Zone of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus
2 Zone of Dicranograptus nicholsoni
1 Zone of Climacograptus typicalis, Glossograptus quadrimucronatus approximatus, and Lasiograptus eucharis

Of these three zones, the lowermost appears to be the thickest. It reaches 500 feet in the Otsquago creek section.

The second zone, that of Dicranograptus nicholsoni, is known best from the Otsquago section where it may reach 150 feet.

The third zone is characterized by Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus. Its thickness is less than 200 feet, and counting about 50 feet of nonfossiliferous transition beds with the Frankfort, not more than 150 feet should be assigned to this division.

Type Section at Utica. Starch Factory creek, Utica. According to Vanuxem (1842, p. 58) the Utica shale received its name from its exposures " in the creek east of the city." There are two creeks, Ballou creek and Starch Factory creek, flowing through the eastern part of the city of Utica. It is doubtful which of the two Vanuxem had in mind, presumably Ballou creek, which is no longer accessible. As the two creek sections run parallel, across the strike of the beds, within 1½ miles of each other, they have identical faunal zones. We have followed Starch Factory creek from its mouth to the Frankfort shale exposures in the hills back of Utica.

The first exposure is near its mouth, just above the track of the New York Central Railroad. Here is found black shale which contains:

Climacograptus pygmaeus Rued. cc
Climacograptus typicalis Hall c
Glossograptus quadrimucronatus timidus Rued. c
Mastigograptus simplex (Walcott) r
Leptobolus insignis Hall
Triarthrus eatoni (Hall)

The fauna characterized by Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus could be traced in outcrops along the creek to above the Masons' home altogether through about 90 feet of rock (taking the dip of the beds into account).

A mile farther southwest and about 140 feet higher up in the section, the shale exposed in a cliff along the same creek, becomes more fissile and argillaceous, weathering gray, and indicating approach to the Frankfort beds. It contains

Climacograptus pygmaeus Rued. cc
Climacograptus typicalis Hall r
Mastigograptus cf. tenuiramosus (Walcott) (fragment)
Leptobolus insignis Hall c
Geisonoceras tenuistriatum (Hall)

Another half mile in the same direction and 65 feet higher in the section, distinct Frankfort transition beds are exposed, consisting of black argillaceous shale with interbedded gray sandy shale and gray sandstone. These beds contain:

Climacograptus typicalis Hall r
Leptobolus insignis Hall r
Camarotoechia (?) humilis Rued.
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall) (small form)

This is a Frankfort faunule.[1]

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[1] See Frankfort fauna, p. 58.

It appears from these faunules that in the type section of the Utica shale in Starch Factory creek only the uppermost graptolite zone, that of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus is exposed, ranging here through 250 feet of rock.

Well-sections, published by Prosser (1900, p. 137) prove that at the canal bank at Utica the Utica shale was passed at a depth of 543 feet, giving to the Utica shale in its type locality a thickness of nearly 800 feet (the dip being so small that it is negligible in the well record), provided that no Trenton shales extend as far from the east. There is hence, only the upper third of the Utica shale exposed in the Starch Factory creek section, the other two being hidden in the deeply drift-filled Mohawk valley. It was for this reason thought necessary to extend the type section of the Utica shale across the river northward to Holland Patent, about 10 miles distant from Utica, where supposed lower beds of the Utica shale are exposed close to the Trenton limestone.

Utica exposures about Holland Patent. The Utica exposures in the town of Trenton, Oneida county, N. Y., and especially those about Holland Patent have gained paramount importance through the fact that Rust and Walcott obtained there the collections from which Walcott and Rauff described the remarkable sponge faunules and Walcott also a variety of other fossils, notably peculiar graptolites as Mastigograptus simplex and tenuiramosus, Leptograptus annectans and Callograptus complexus. It was also here that Pleurograptus linearis was obtained.

These beds, as pointed out by Miller (1909, p. 21) are shown in sharp contact with the Trenton limestone in the bed of Nine Mile creek, 1½ miles southeast of Holland Patent. "A low anticline here brings up the upper Trenton limestone with Utica shale resting on either limb." Another outcrop, also within a few feet of the Trenton is observed in the bed of the brook at the village of South Trenton. Other outcrops of Utica shale also occur in the ravines north and northwest of Holland Patent. It is there separated from the Trenton in the south by a line of disturbance and northward grades into the Frankfort shale.

The writer has, in New York State Museum Bulletin 162 (1912, p. 27) proclaimed this Holland Patent fauna as characterizing the "base of the typical Utica," because of its occurrence close to the Trenton limestone. It was, however, found necessary there to point out that the basal Utica beds east of Utica, in the Dolgeville-Jacksonburgh section contain a different fauna. It was added (*ibid.* p. 28) that it is probable that the "basal" Utica at Dolgeville-Jacksonburgh and that at Utica do not represent the same horizons, and if so, the former is probably older than the latter.

Meanwhile the observation of the continuous section at the Ohisa-Nowadaga creek and the differentiation of three distinct zones in the Utica, the lowest of which contains a fauna different from that found at Holland Patent, and especially the fact of the abundance of Climacograptus pygmaeus and frequent occurrence of Glossograptus quadrimucronatus timidus — the two most characteristic graptolites of the upper Utica shale — in the Holland Patent material threw serious doubt on the early Utica age of the Holland Patent fauna. A renewed close examination of the Holland Patent outcrops has shown that all belong into the upper third of the Utica.

The above-mentioned outcrop in Nine Mile creek, within 5 feet of the massive crystalline crinoidal limestone, characteristic of the lower Cobourg at Trenton falls, has furnished the following faunule:

Callograptus compactus (Walcott) r
Leptograptus annectans (Walcott) r
Climacograptus typicalis (Hall) c
C. pygmaeus Ruedemann c
Lasiograptus eucharis (Hall) c
Glossograptus qu. timidus Ruedemann c
Leptobolus insignis Hall c
Geisonoceras tenuistriatum (Hall) rr

An outcrop in the creek at the other side of the anticline, at the second bridge across the creek, east of Holland Patent contains:

Callograptus compactus (Walcott) c
Leptograptus annectans (Walcott) c
Corynoides ultimus Ruedemann rr
Diplograptus recurrens uticanus Ruedemann r
Climacograptus typicalis Hall c
C. pygmaeus Ruedemann cc
Glossograptus qu. timidus Ruedemann c
Lasiograptus eucharis (Hall) r
Leptobolus insignis Hall c
Triarthrus eatoni (Hall) r

At an earlier visit this locality had furnished a specimen of Cyathodictya reticulata (Walcott), and fragments of Mastigograptus.

The locality at South Trenton, also close to the Trenton limestone, has afforded the following:

Teganium subsphaericum Rauff rr
Callograptus compactus (Walcott) c
Leptograptus annectans (Walcott) c

Diplograptus recurrens uticanus Ruedemann r
Climacograptus typicalis Hall c
C. pygmaeus Ruedemann cc
Lasiograptus eucharis (Hall) c
Leptobolus insignis Hall c
Camarotoechia (?) humilis Ruedemann rr

Finally, the ravines north and northwest of Holland Patent, which contain about 200 feet of typical Utica shale between the Frankfort shale on top and the fault line at the base, have furnished:

Discophycus typicalis Walcott (near base)
Mastigograptus simplex (Walcott) (near top)
M. tenuiramosus (Walcott) (near base)
Climacograptus typicalis Hall
C. pygmaeus Ruedemann
Glossograptus qu. timidus Ruedemann c
Leptobolus insignis Hall
Camarotoechia (?) humilis Ruedemann
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall)

The comparison of these faunules leaves no doubt that at Holland Patent only the upper division of the Utica, that of Climacograptus pygmaeus and Glossograptus qu. timidus is exposed and that this rests directly on the Trenton limestone.

It is also obvious that this upper Utica shale is the horizon containing the supposed "basal Utica fauna" of Mastigograptus simplex, M. tenuiramosus, Leptograptus annectans, the sponges, etc., all of which were originally obtained about Holland Patent, and some of which were also collected there by the writer, as Sphaerodictya subsphaerica (Walcott) in the Marcy section, Cyathodictya reticulata, Teganium and Discophycus typicalis at Holland Patent. It should here be also remembered that a species of Cyathodictya was collected in the upper Utica beds of the Ohisa section; and further that Mastigograptus simplex and tenuiramosus, as well as Leptograptus annectans appear in the upper Utica shale at the Starch creek section at Utica, Maynard creek section and Marcy creek section, in the same association of forms, but are absent in the lower and middle Utica in the Ohisa section, save Leptograptus annectans, that appear there in the middle division. These same forms continue to appear together farther north (see below Mill Creek section at Turin, etc.) in the Black river valley.

The thickness of this upper division of the Utica, that alone is present at Holland Patent, is between 300 and 400 feet. Exact data were not obtained here since the upper boundary of the Utica was not found clearly exposed on the northern slope of Marcy hill, south of South Trenton. Five miles to the north of Holland Patent, in the Trenton Valley section (see below p. 42 and Miller, 1909, p. 21) the Utica shale is something over 300 feet. The Utica has then, in the short distance of 10 miles, from Utica to Holland Patent, shrunk from about 800 feet to 300–400 feet. This amazing decrease is, in our view, explainable only by the assumption that the middle and lower Utica have suddenly dropped out, only the upper Utica overlapping on the Trenton north of Utica.

This abrupt change in thickness of the Utica in this region is in full accord with that of the Trenton limestone which decreases from 510 feet at Utica (see Miller p. 18) to about 300 feet at Trenton. It is then to be assumed that the Utica region was an area, in Trenton and Utica time, that was more rapidly sinking than the regions to the north and west.

The typical Utica fauna. The large fauna of Holland Patent, now known to belong to the upper division of the Utica instead of near the base, was secured through the untiring efforts of Rust, Walcott and Haskell from beds that are by no means profuse in fossils except the common graptolites of the genus Climacograptus. This fauna has come to be looked upon as the typical Utica fauna, and properly so as it is that of the single division exposed at Utica.

As the most characteristic forms of the Utica shale at Holland Patent have before been cited by the writer, in New York State Museum Bulletin, 162, p. 27, the following species:

Mastigograptus simplex (Walcott)
Mastigograptus tenuiramosus (Walcott)
Pleurograptus linearis (Carruthers)
Leptograptus annectans (Walcott)
Dicranograptus nicholsoni Hopkinson
Climacograptus typicalis Hall
Lasiograptus eucharis (Hall)
Glossograptus quadrimucronatus (Hall) *mut.*
Cyathodictya reticulata (Walcott)
Trocholites ammonius Conrad
Triarthrus becki Green

The following list of Utica fossils from Holland Patent and South Trenton has been made from the Rust and Haskell collections in the New York State Museum and the Rust and Walcott collections in the United States National Museum:

Delesserites salicifolia *nov.*
Discophycus typicale Walcott
Sphenophycus succulentum *nov.*
Cyathodictya reticulata (Walcott)
C. walcotti **(Rauff)**

Sphaerodictya subsphaerica (Walcott)
Teganium subsphaericum Rauff
T. macrosclera *nov.*
Foerstella rotunda *nov.*
F. flabellata *nov.*
Sycodictya rara *nov.*
Pyritonema capilliforme *nov.*
Mastigograptus simplex (Walcott)
M. tenuiramosus (Walcott)
Callograptus compactus (Walcott)
Leptograptus annectans (Walcott)
L. annectans resupinus *nov.*
L. annectans amplectens *nov.*
L. flaccidus (Hall)
Pleurograptus linearis (Carruthers)
Dicranograptus nicholsoni Hopkinson
Diplograptus amplexicaulis uticanus *nov.*
Climacograptus typicalis Hall
C. pygmaeus Ruedemann
Glossograptus quadrimucronatus inequispinosus *nov.*
Lasiograptus eucharis (Hall)
Spatiopora lineata compacta *nov.*
Hemiphragma bassleri *nov.*
Prasopora *aff.* contigua Ulrich
Lingula curta Conrad
Leptobolus insignis Hall
Schizambon minutus *nov.*
Camarotoechia (?) humilis *nov.*
Dalmanella *cf.* testudinaria (Dalman) (small form)
Platystrophia uniplicata uticana *nov.*
Orthorhynchula linneyi (James)
Serpulites angustifolius Hall
S. crassimarginalis Ruedemann
S. gracilis Ruedemann
Cornulites immaturus Hall and Clarke
Conularia papillata Hall
C. granulata Hall
Spirorbis philorthoceras *nov.*
Protoscolex *cf.* covingtonensis Ulrich
Pterinea insueta (Emmons)
Whiteavesia (?) perstriata *nov.*
Rhytimya cancellata (Walcott)
Cuneamya subquadrangularis *nov.*
Strophostylus gregarius *nov.*
Holopea varicosa *nov.*
Geisonoceras tenuistriatum (Hall)
G. amplicameratum (Hall)
G. strigatum (Hall)
G. *sp. indet.*
Endoceras *cf.* proteiforme (Hall)
E. perannulatum *nov.*
Protokionoceras oneidaense (Walcott)
Spyroceras bilineatum (Hall)
Cycloceras persculptum *nov.*
Trocholites ammonius major *nov.*
Isotelus stegops Green
Triarthrus eatoni (Hall)
T. spinosus Billings
Bollia uticana *nov.*
B. *sp. aff.* pulchra *nov.*
Aparchites minutissimus (Hall)
Ceratiocaris timida *nov.*

Eobalanus informans Ruedemann
Echinognathus clevelandi Walcott
Eurypterus rusti *nov.*
Pterygotus walcotti *nov.*
Hughmilleria uticana *nov.*
Eusarcus breviceps *nov.*
Dolichopterus (?) insolitus *nov.*

The most important graptolite of this faunule is probably Pleurograptus linearis (Carruthers), although it was found only in a few specimens, because it characterizes a zone in the Hartfell shale. Another important graptolite is Leptograptus flaccidus, because it is, on this side of the Atlantic, only known so far from the Gloucester shale of Canada. This graptolite, together with some other fossils, notably Triarthrus spinosus allows the correlation of that Canadian Utica shale with the third division of our Utica shale. Of the other graptolites, Lasiograptus eucharis has its principal range below the Utica. L. annectans occurs also in the Fulton shale at Cincinnati (see Museum Memoir 11, p. 265) and has since been observed by the writer in the Canajoharie shale at Crescent (see Bulletin 162, p. 31), where it is associated with Corynoides calicularis and other Canajoharie graptolites, and, as will be recorded farther on, in higher horizons of the Utica. Dicranograptus nicholsoni is very common near the top of the Glenkiln shales, and in the lower Hartfell shales of Great Britain. We have it on this side, in several mutations already in the Normanskill shale (see Memoir 11, p. 320 ff.), and it has also been observed in the Fulton shale of the Ohio basin (*ibid.* p. 319), and the writer has recorded this species in Bulletin 162 from the Snake Hill beds, the Canajoharie shale, and even the Indian Ladder beds. Near South Trenton, Oneida county, it has been found about 6 to 10 inches above the Trenton limestone. On account of its great range this graptolite would not seem well suited for an index fossil of a horizon, nevertheless, it is distinctly a rare fossil in the Utica shale, except in the beds in the middle of the formation where it is the dominant, common fossil through about 100 feet of rock. Outside of this occurrence and the specimens in the basal beds near Trenton falls I have never observed it in the Utica shale. It is therefore a characteristic fossil of that horizon. Moreover, it is undoubtedly possible to distinguish the occurrences in the different formations as mutations by minute differences, if it is desired, and as a matter of fact some of these have already been recognized by the writer.

Climacograptus typicalis occurs in such immense numbers on most graptolitiferous surfaces of the Utica near Trenton that it is distinctly the dominant graptolite of that horizon. The two species of Mastigograptus have been secured in their best representatives in the upper Utica beds at Holland Patent, but they are in this bulletin recorded from still higher horizons and even go into the Frankfort and Lorraine shale.

While none of the graptolites, with the possible exception of Pleurograptus linearis, seems to be restricted to these upper Utica beds, their combined occurrence produces a peculiar faunal aspect that is nowhere fully repeated in the Utica shale.

The dominant graptolite of the upper Utica is however, in the basal beds at Holland Patent, as well as throughout the division in the Ohisa, Holland Patent and other sections the minute Climacograptus pygmaeus. This covers a majority of the fossiliferous bedding-planes to the exclusion of other forms. On account of its small size it has obviously been overlooked by other collectors. While Glossograptus qu. timidus is a characteristic fossil of the division throughout its thickness, Callograptus compactus is only common in the lowest portion of the division about Holland Patent and seems to be especially typical of these lowest beds of the upper Utica. It is followed in importance by the two species of Mastigograptus which have not been observed below the upper Utica, but seems to range through this and beyond it.

These graptolites together with the species of Cyathodictya, Sphaerodictyum and Teganium give the upper Utica fauna an aspect quite different from the middle and lower Utica; and the presence of Triarthrus spinosus and Leptograptus flaccidus hitherto known only from the Gloucester shale of Canada is quite suggestive of temporary connection of the northern margin of the Utica sea with the Gloucester sea invading from the North Atlantic.

Maynard creek section, Marcy, N. Y. An interesting section was observed by the writer along Maynard creek, 1½ miles north of Utica.

The section affords a practically continuous outcrop of black shale through 150 feet of rock. At the base are found:

Climacograptus typicalis Hall and
Triarthrus eatoni (Hall)

Thirty feet higher up there appear

Leptograptus annectans (Walcott) *mut.*
Climacograptus typicalis Hall
Climacograptus pygmaeus *nov.*
Leptobolus insignis Hall
Triarthrus eatoni (Hall)

Leptograptus annectans can be traced as a rather frequent graptolite through 30 feet of black shale, and with it occur

Mastigograptus tenuiramosus (Walcott) r
Climacograptus pygmaeus *nov.* cc
Leptobolus insignis Hall r
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall) c

In the remaining 90 feet of the section only Climacograptus pygmaeus was found, but in immense numbers. This upper shale with Climacograptus pygmaeus can be traced in adjoining creeks into the Frankfort beds that cap the Deerfield range.

It is obvious that in this section only the uppermost Utica with Climacograptus pygmaeus is exposed. The more remarkable is then the continuance of Leptograptus annectans together with Mastigograptus tenuiramosus.

Section along Marcy creek, Oneida county, N. Y. Three and one-half miles northwest of Maynard creek is the section of Marcy creek which in former years has furnished a number of the rarer Utica fossils. It also extends to the level of the Mohawk river and thus completes the Maynard section.

The whole 140 feet of almost continuous section exposed along the creek from the neighborhood of the Marcy railroad station down to its entrance into the flood plain of the Mohawk river is within the upper zone.

In the lowest outcrops, at station 3, above and below the bridge of the Utica-Rome highway Climacograptus pygmaeus and Leptobolus insignis were found, the first in great abundance.

At station 2, 20–40 feet higher up, and about the lower end of the gorge of Marcy creek, there occur in thick-bedded black mud-shale:

Sphenophycus lobatus *nov.* rr
Sphaerodictya subsphaerica (Walcott) rr
Leptograptus annectans (Walcott) r
Climacograptus pygmaeus *nov.* cc
C. typicalis Hall r
Leptobolus insignis Hall c
Camarotoechia (?) humilis *nov.*
Dalmanella *sp. cf.* testudinaria (Dalman) (small specimens) r
Endoceras *sp.* (fragments)
Triarthrus eatoni (Hall) c
Eurypterid fragments

The remainder of the section through the ravine and as far up as the railroad bridge below Marcy station furnished in heavy bedded black shales:

Climacograptus pygmaeus *nov.* cc
C. typicalis Hall r
Leptobolus insignis Hall r
Schizocrania filosa Hall c
Endoceras *sp.* r
Triarthrus eatoni (Hall) c

It is obvious, from the sections in the city of Utica and the two sections just described north of the Mohawk, in the town of Deerfield, that in the immediate neighborhood of Utica only the uppermost division of the Utica shale is exposed in the Mohawk valley.

Summary of sections east and north of Utica. A survey of the Utica sections thus far recorded indicates that there are three major graptolite zones developed in the Utica shale of the middle Mohawk valley and the Utica region. These are, in descending order:

3 Zone of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus
2 Zone of Dicranograptus nicholsoni
1 Zone of Climacograptus typicalis, Glossograptus quadrimucronatus approximatus, and Lasiograptus eucharis

Of these three zones, the lowermost appears to be the thickest in the Mohawk valley below Utica. It reaches 500 feet in the Otsquago creek section, and is probably as much in the Utica section.

The second zone, that of Dicranograptus nicholsoni, is known only from the Otsquago and Ohisa sections where it may reach 170 feet.

Of the third zone, nearly 200 feet are exposed in the Starch Factory creek section and the bottom not shown.

Sections West and North of Utica

Six Mile creek, about 7½ miles west of Holland Patent. At this locality, which became famous by the discovery, by Valiant, of the pyritized specimens of Triarthrus eatoni, retaining the appendages, and described by Beecher, the base of the section contains Climacograptus typicalis, Glossograptus quadrimucronatus approximatus and Triarthrus eatoni, while the succeeding 100 feet that are exposed contain first Climacograptus typicalis, often in great numbers, together with Leptobolus insignis, etc., and finally Climacograptus pygmaeus as diagnostic species. In lithologic character, all the beds, except the lowest exposure, are transitional to the Frankfort and the occurrence of the pyritized Triarthrus is in a bed of black shale, intercalated in gray argillaceous shale of Frankfort appearance.

Seven miles northwest of Holland Patent, along Big Brook at Westernville, a fine contact of Trenton limestone and Utica shale is exposed for a long distance.

The Trenton limestone is a thick-bedded crinoidal limestone with many bryozoans, Rafinesquina camerata, Dinorthis *cf.* iphigenia (Billings), Platystrophia lynx, large form of Plectambonites sericeus, Zygospira recurvirostris and fragments of Isotelus.

The contact with the Utica is sharp and probably disconformable. The Utica shale contains in the basal beds Lasiograptus eucharis and Climacograptus tenuis.

Steuben creek, Oneida county. Along Steuben creek, in the town of Steuben, 5 miles north of Holland Patent, about 300 feet of Utica shale are exposed. The last Trenton limestone observed is crinoidal Cobourg limestone. The first outcrop of shale occurs 130 feet above this, but the limestone may, judging from surrounding conditions, rise about 40 feet higher in the section. This shale contains in the lowest 20 feet:

Glossograptus quadrimucronatus approximatus Rued. c
Lasiograptus eucharis Hall cc
Climacograptus pygmaeus *nov.* cc
Spatiopora lineata Ulrich *mut.* crassijuncta *nov.* r
Camarotoechia (?) humilis nov.
Geisonoceras amplicameratum (Hall) c
Triarthrus eatoni (Hall) c

The Climacograptus pygmaeus occurs in immense numbers in the first 5 feet and is about 15 feet higher up, succeeded by prevailing Lasiograptus eucharis.

This zone is followed 20 feet higher up by shales with

Climacograptus typicalis Hall r
Climacograptus pygmaeus *nov.* cc
Leptograptus annectans (Walcott) r
Triarthrus eatoni (Hall) cc

Sixty feet higher up fossiliferous shale affords:

Climacograptus pygmaeus *nov.* cc
Schizocrania filosa Hall r
Triarthrus eatoni (Hall) c

Thence black shales were traced about 200 feet higher up, much of it in continuous section; the upper 100 feet were slightly changed in lithic character, the black shale being more micaceous, argillaceous or at times sandy, and less calcareous, thus indicating a very gradual passage into the overlying Frankfort beds. In fossil content these shales are relatively barren. While Leptobolus insignis, an Endoceras (proteiforme auct.) and Triarthrus eatoni are everywhere present, the latter even in great numbers in some layers, graptolites become increasingly rare as one rises in the section, only scattered specimens of Climacograptus typicalis and Cl. pygmaeus being observable. A fragment of Mastigograptus *cf.* tenuiramosus was also noted.

The base of this section suggests by the presence of Glossograptus quadrimucronatus approximatus and Lasiograptus eucharis the basal beds of the third zone, leaving but about 100 feet below for the lower two zones. The rest of the section belongs all in the third zone, which there occupies 300+ feet.

In a brook coming from Quaker hill opposite Westernville, the uppermost 65 feet of the Utica shale are exposed. This somewhat micaceous shale is again rather barren. It affords:

Climacograptus typicalis Hall r
Climacograptus pygmaeus *nov.* r
Leptobolus insignis Hall c
Geisonoceras *sp.* r
Triarthrus eatoni (Hall) r

North of Northwestern, near Hillside, where the Quaker hill road crosses the Mohawk river, another long section begins that runs along a brook coming from Quaker hill. Here 80 feet of Utica shale are exposed, followed by Frankfort beds. Here again the shale is relatively barren, containing scattered specimens of Climacograptus pygmaeus, Mastigograptus tenuiramosus and Triarthrus eatoni.

Summary of sections of Utica shale in Mohawk river basin. The Nowadaga-Ohisa section had brought out the fact that the Utica shale in its fullest development reaches a thickness of 800 feet in the Mohawk valley and consists of three distinct divisions.

The lowest division, about 500 feet thick in that section, is characterized by Climacograptus typicalis, Glossograptus quadrimucronatus approximatus, and Lasiograptus eucharis.

The middle division, about 150 feet thick there, is that of Dicranograptus nicholsoni.

The upper division, also about 150 feet thick there, is the zone of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus.

Going west from the meridian of Ohisa creek, the two lower divisions become, owing to the southwest dip of the beds, rapidly buried under the Mohawk alluvium, not to be uncovered again.

In the historic type-section of the Utica shale, at Utica, only the upper division is exposed, and this incompletely, although 250 feet of it are shown along Starch Factory creek. Since well-sections at Utica have brought out a thickness of nearly 800 feet for the black shale between the Trenton and Frankfort, it is to be assumed that all three divisions, and perhaps even a slight representation of the Canajoharie extend to the meridian of Utica, but fail to become uncovered in the deeply drift-filled Mohawk valley. It is probable, however, that the third division has become greatly thickened at the expense of the two lower ones. West and south of Utica the Utica formation is buried under younger formations; while northward the formation continues as a belt into the Black river valley.

In following this belt in northward direction from Utica, it was found that 10 miles to the north, at Holland Patent, only the third division is left and that this rests upon the Trenton limestone (lower Cobourg limestone) with a thickness of about 300 feet. The two lower divisions thus end abruptly to the north of the upper Mohawk valley, although they may continue still to the west and south.

The sections given in the next chapter will show that this third division of the Mohawk-Utica also disappears rather rapidly northward of Holland Patent in the upper reaches of the Black river valley and that it is replaced by a black shale with a different faunule appearing above it.

Black River Valley Sections

Moose creek, near Boonville. An excellent section, practically from the Trenton limestone to the upper Lorraine is exposed along the north branch of Moose creek near Boonville, about 17 miles as the crow flies, and a little west of north, from Holland Patent and 25 miles from Utica.

The Utica shale has here, according to Miller (1910, p. 32) been reduced to 300 feet[1].

The first outcrop of shale is 20 feet above the Trenton, a crinoidal limestone here. It contains

Climacograptus typicalis Hall
Mastigograptus *sp.* (fragment)
Leptobolus insignis Hall
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall)

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[1] From our measurement we believe it to be even less, namely, to reach from 1180 feet A. T. to 1300 A. T.=120 feet; + 100 feet, owing to the southwesterly dip of about 50 feet in a mile, or altogether not more than 250 feet.

The same fossils, together with Zygospira modesta (Say) and a large Plectorthis (*cf.* fissicosta), and Climacograptus pygmaeus were observed through 40 feet of rather barren shale; then Climacograptus pygmaeus became the most common fossil and was found associated with Glossograptus quadrimucronatus timidus. This combination could be traced to the 1300-foot contour line at Pasadena, where just below the Frankfort shales a 12-foot zone filled with Climacograptus typicalis posterus *nov.* is exposed.

Mill creek near Turin. Following the Black river valley northward, another excellent section from the Trenton limestone to the Lorraine is found along Mill creek above Turin, 10 miles north-northwest of the preceding section. The black shale is here no thicker than 230 feet while the Trenton limestone has increased to 400 feet by the addition of beds on the top.

At the base no more than 40 feet above the Trenton black micaceous shale is found with:

Climacograptus typicalis Hall c
Mastigograptus laevis (Hall) r
Leptobolus insignis Hall r
Geisonoceras *sp.* (very large form) c
Triarthrus eatoni (Hall)

Thirty feet higher up occur:

Mastigograptus laevis (Hall) c
Mastigograptus tenuiramosus (Walcott) c
Leptograptus annectans (Walcott) c
Leptobolus insignis (Hall) cc
Camarotoechia (?) humilis *nov.* c
Geisonoceras tenuistriatum (Hall) c
Triarthrus eatoni (Hall) (very large) c

Another 30 feet up a 90-foot cliff of black shale contains

Climacograptus pygmaeus *nov.* cc
Climacograptus typicalis posterus *nov.* cc
Mastigograptus laevis (Hall) r
Camarotoechia (?) humilis *nov.* r

Above this Climacograptus typicalis posterus fills the black shale to the exclusion of other graptolites, where exposures occur, as 210–25 feet above the Trenton, and in several outcrops still higher up. At about 300 feet above the Trenton, (1610-foot level) at the upper bridge across the creek, gray and black shales with sandy layers, of the appearance of the Frankfort beds prevail (see below, p. 56).

Whetstone gulf, near Martinsburg. One of the finest Utica-Lorraine sections in the Black river valley is found in the Whetstone gulf near Martinsburg, where there is a continuous exposure of over 600 feet of rock (530 feet by aneroid measurement + 100 feet on account of a southwestward dip of 50 feet in the mile).

The black shale has in this section been reduced to a thickness of 180 feet, 120 feet of which are exposed. The lowest Utica outcrop at the mouth of the "Gulf" is about 60 feet above the top of the Trenton limestone.

It contains

Diplograptus (Mesograptus) levis *nov.*
Plectorthis *cf.* fissicosta (Hall) r
Camarotoechia (?) humilis *nov.* r
Pterinea insueta *mut. nov.* r
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall) c

This faunule is found in the lowest 25 feet. Then occur:

Climacograptus typicalis posterus *nov.* cc
Plectorthis *cf.* fissicosta (Hall) r
Leptobolus insignis Hall cc
Pterinea insueta *mut. nov.* r
Geisonoceras tenuistriatum (Hall) c
Triarthrus eatoni (Hall)

Twenty feet higher up are found:

Climacograptus typicalis posterus *nov.* c (very narrow form)
Glossograptus quadrimucronatus (Hall) *mut.* c
Mastigograptus laevis (Hall) c
Leptobolus insignis Hall c
Geisonoceras tenuistriatum (Hall)
Triarthrus eatoni (Hall) c

This shale continues upward, gradually assuming the characters of the Frankfort shale, until 50 feet higher up the shale is distinctly grayish and thin sandy layers appear (see p. 57).

Atwater brook, Martinsburg. This section begins with the Trenton which is finely exposed along the brook for a mile above its mouth, and runs in fairly continuous exposures through the Utica into the Frankfort. This upper part of the Trenton limestone, mostly crinoidal in character, contains, besides Rafinesquina deltoidea, Platystrophia lynx, Streptelasma corniculum, Dalmanella testudinaria, Sinuites cancellatus, also Fusispira subfusiformis and Trochonema umbilicatum. It therefore corresponds to Raymond's Cobourg formation which is younger than the Trenton at Trenton Falls.

Twenty feet above the top of this limestone the black shale begins, as usually in the Black river valley, with heavy bedded compact black mud-shale, in which graptolites are rare. It contains:

Climacograptus typicalis Hall r
Leptobolus insignis Hall c
Camarotoechia (?) humilis *nov.*
Geisonoceras tenuistriatum (Hall) c
G. amplicameratum (Hall) c
Triarthrus eatoni (Hall) cc (large)

This fauna with the addition of a few specimens of Climacograptus pygmaeus and Schizocrania filosa can be traced through 50 feet of rather barren compact mud beds. Then are found:

Diplograptus (Mesograptus) levis *nov.* c
Leptobolus insignis Hall cc
Camarotoechia (?) humilis *nov.*
Triarthrus eatoni (Hall) c

Twenty-five feet higher up in like compact mud-shale there appear:

Climacograptus typicalis posterus *nov.* cc
Glossograptus quadrimucronatus approximatus Rued. r

together with the brachiopods, cited above, and Orthoceras *sp.*

This faunule with Climacograptus typicalis posterus as the sole common fossil, can be traced through 55 feet of black shale, after which the shale begins to get gray and sandy layers appear. The faunule with Climacograptus typicalis posterus *nov.* continues into these shales of Frankfort appearance (see p. 57).

Deer river, Copenhagen. The northernmost Utica section on the west side of the Adirondacks, is along the Deer river above Copenhagen. Here the black shale begins about 25 feet above the top of the Trenton. It contains:

Climacograptus typicalis posterus *nov.* cc
Glossograptus quadrimucronatus timidus *nov.* r
Leptobolus insignis Hall r
Camarotoechia (?) humilis *nov.* r
Geisonoceras tenuistriatum (Hall) c

This faunule, together with Climacograptus pygmaeus, can be traced throughout the black shale exposed, 45 feet of rock. Then follow the thin, fissile, argillaceous gray shales with sandy bands of Frankfort appearance, which, however, contain the same fauna (see p. 57).

Lorraine gulf. The black shales at Allendale, at the mouth of the Lorraine gulf, which have currently been considered as representing the Utica shale, are discussed under the heading Frankfort beds, on page 57 because they are above the typical Utica.

The top of Trenton limestone is well exposed on the south branch of Sandy creek, 2½ miles below the Allendale bridge, where the Lorraine section begins. The limestone contains among others:

Plectambonites sericeus (Sowerby) cc
Platystrophia lynx (Eichwald) c
Rafinesquina deltoidea (Conrad) c
Fusispira subfusiformis (Hall) c
Hormotoma bellicincta (Hall)
Trochonema umbilicatum (Hall) cc

and is undoubtedly referable to the Cobourg limestone.

The shale begins 90 feet, by aneroid, above the limestone, to which is to be added 125 feet on account of the dip. The black shale at Allendale is therefore 215 feet above the Trenton limestone and, considering the thickness of the black shale at the nearby locality Copenhagen, surely far above the Utica shale and near the top of the Frankfort, a conclusion which is borne out by the fauna (see p. 57).

Summary of sections north of Utica region. In the summary of the sections east of the Utica region (p. 31) it was shown that the Utica shale in the Mohawk valley at Utica and below that city can be divided into three zones, the lowest of which is characterized by Climacograptus typicalis, Glossograptus quadrimucronatus and Lasiograptus eucharis. The middle zone has as diagnostic form, Dicranograptus nicholsoni, and the upper zone is recognized by the presence of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus.

In going west and north of the Utica region, no trace of the middle zone has been found. At Six Mile creek the lower and upper zones could be recognized; on Steuben creek only the third zone was observed, but the first may be covered in the unexposed hiatus of over 100 feet above the Trenton limestone. At any rate, the third zone has swelled here to 300 feet and this occupies by far the greatest part of the Utica shale. The third zone was likewise found in the sections about Northwestern, in brooks coming from Quaker hill. Along Moose creek, near Boonville, 25 miles north of Utica the black shale is reduced to 250 feet, and of this only the lowest 20 feet may belong to the first zone, the rest to the third with the exception of a narrow zone (12 feet exposed) just below the Frankfort, where a new zone-graptolite, that of Climacograptus typicalis posterus *nov.* makes its appearance.

Ten miles farther north, along Mill creek near Turin, the black shale is no thicker than 230 feet. Here the zone with Climacograptus pygmaeus begins about 100 feet from the base, and this fossil ranges through about 90 feet of rock, after which the zone with Climacograptus typicalis posterus begins. This zone has here already a thickness of at least 40 feet which are exposed. How far it reaches into the Frankfort transition beds is not known in this section.

In the section of Whetstone gulf near Martinsburg, 12 miles northwest, the black shale is reduced to 180 feet, of which the upper 160 feet are exposed. All this distinctly belongs in the zone with Climacograptus typicalis posterus with the exception of the lowest 25 feet where another graptolite, Diplograptus (Mesograptus) levis is the sole form found. The lower beds here covered, are exposed along Atwater brook, a few miles farther north. Here the lowest beds seen may still belong to the lower graptolite zone; the next 50 feet contain Climacograptus pygmaeus; the next 25 feet the faunule with Diplograptus (Mesograptus) levis; and the remainder is filled with Climacograptus typicalis posterus, which also extends into the overlying beds of Frankfort character. On Deer river near Copenhagen, where the black shale is reduced to 70 feet, only the zone with Climacograptus typicalis posterus was found, the lower 25 feet not being exposed.

We infer from these sections that the second zone does not extend into the Black river valley, or north of Utica, that the lowest zone rapidly disappears and the third zone occupies nearly the entire thickness of the black shale. But 25 miles north of Utica, in the Moose creek section near Boonville, a still higher zone, that of Climacograptus typicalis posterus, appears at the top of the black shale. This gains, with some irregularities, as one goes north, at the expense of the third zone, that with Climacograptus pygmaeus, until in the last section on Deer river, only this fourth zone is found.

In a general way, therefore, going northward from Utica, the first and second zones become thinner and finally disappear, whereas the third continues a greater distance and may in places constitute the whole of the black shale interval, and finally a new still higher zone is added to the section. Hand in hand with this phenomenon goes the remarkable decrease in the total thickness of the black shale from 800 feet at Utica to 70 feet at Copenhagen; and the corollary of this again is the thickening of the Trenton limestone from 300 feet at Trenton Falls to 475 feet at the Atwater brook. This thickening is in part explained by the intercalation above the Trenton limestone of a new limestone formation namely, the Cobourg limestone of the Canadian Survey. The Cobourg limestone thus wedges in from the north and occupies the interval held in the south by the two lower Utica shale zones, until finally also the third zone drops out of the section. The new fourth zone, with Climacograptus typicalis posterus overlies the Cobourg and possibly corresponds to a part of the Collingwood shale of the Ottawa basin, formerly "Utica shale," which there rests upon the Cobourg limestone. This upper black shale, being clearly younger than the Utica and without the typical Collingwood fauna will be termed the Deer River shale by us. In other words, the true Utica shale thins gradually out northward and disappears in the Black river valley where the Deer river comes in from the north (see figs. 3 and 6).

SUMMARY OF THE GRAPTOLITE ZONES OF THE BLACK SHALE OF THE MOHAWK AND BLACK RIVER VALLEYS

We will now survey the zonal composition of the entire belt of black graptolite shale, formerly known as "Utica shale," that extends from the mouth of the Mohawk at Cohoes to the neighborhood of the mouth of the Black river.

We have shown in a former publication (N. Y. S. Museum Bulletin 162) that the black shale of the lower Mohawk valley is of Trenton age and contains the following zones:

1 Zone of Diplograptus amplexicaulis and Corynoides calicularis
2 Zone of Glossograptus quadrimucronatus cornutus, Corynoides calicularis
3 Zone of Lasiograptus eucharis
4 Zone of Climacograptus spiniferus, Diplograptus vespertinus

This Trenton shale has been termed the Canajoharie shale by the writer. The two lowest zones of this shale are found only along the last 50 miles of the Mohawk river and along the Hudson river, and rest on the basal Trenton limestone, the Glens Falls limestone. The two upper zones while also found in the lower Mohawk and the Hudson valley, reach farther west than the others and finally rest upon and grade into higher Trenton limestone beds (Dolgeville beds of Cushing).

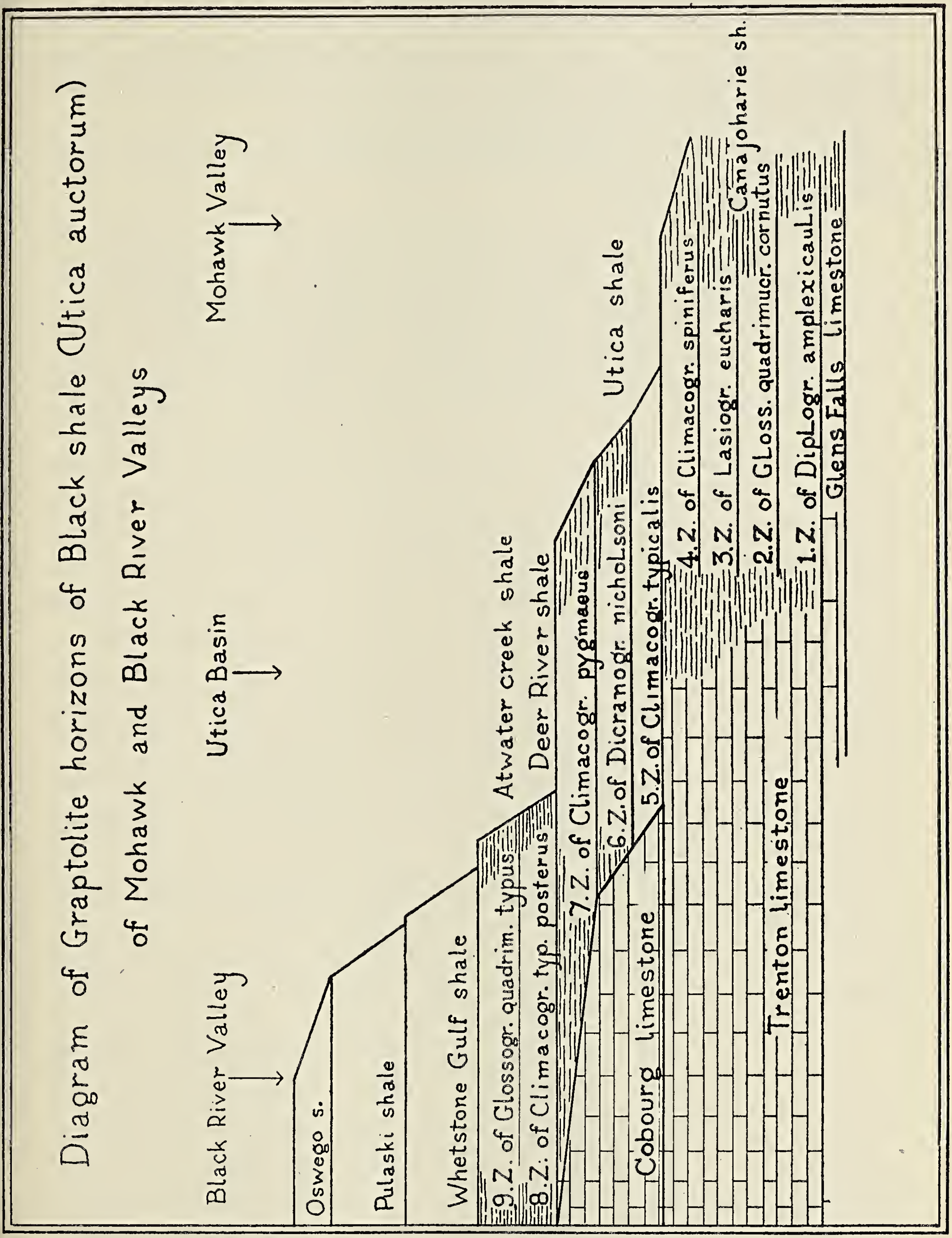
Diagram of Graptolite horizons of Black shale (Utica auctorum)
of Mohawk and Black River Valleys
Black River Valley
Utica Basin
Mohawk Valley
Oswego s.
Pulaski shale
Whetstone Gulf shale
Atwater creek shale
Deer River shale
Utica shale
9.Z. of Glossogr. quadrim. typus
8.Z. of Climacogr. typ. posterus
7.Z. of Climacogr. pygmaeus
6.Z. of Dicranogr. nicholsoni
5.Z. of Climacogr. typicalis
4.Z. of Climacogr. spiniferus
3.Z. of Lasiogr. eucharis
2.Z. of Gloss. quadrimucr. cornutus
1.Z. of Diplogr. amplexicaulis
Canajoharie sh.
Cobourg limestone
Trenton limestone
Glens Falls limestone

Figure 1

While no true Utica shale has been observed in the lowest Mohawk valley, it rests upon the Canajoharie shale in the middle Mohawk valley (Fort Plain and Dolgeville sections). In the Utica region finally the Canajoharie shale has entirely disappeared and the Utica shale rests directly upon Trenton limestone, that has now swelled from 24 feet about Canajoharie to over 300 feet.

The Utica shale is found in the middle and upper Mohawk valley to consist of three zones:

1 Zone of Climacograptus typicalis, Glossograptus quadrimucronatus approximatus, and Lasiograptus eucharis
2 Zone of Dicranograptus nicholsoni
3 Zone of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus

Of these three zones, the second which is the thinnest of the three at its type section along Loyal creek, near Fort Plain, has not been recognized in the Utica region or anywhere farther north. Following the Black river valley it is there found that the first or lowest of the Utica zones thins and gradually disappears first, and that the third finally also disappears while a still younger zone, that of Climacograptus typicalis posterus comes in which at the northernmost outcrop of the "Utica shale" at Copenhagen, appears to occupy the entire belt of black shale. This zone rests on the Cobourg limestone, which is younger than the Trenton limestone, and it is itself younger than the Utica shale. It is here termed the *"Deer River shale."*

Altogether we can then distinguish eight larger graptolite zones in the black shale belt, namely, in descending order:

Deer River shale	8 Zone of Climacograptus typicalis posterus
Utica shale	7 Zone of Climacograptus pygmaeus and Glossograptus quadrimucronatus timidus 6 Zone of Dicranograptus nicholsoni 5 Zone of Climacograptus typicalis, Glossograptus quadrimucronatus approximatus, etc.

Canajoharie shale	4 Zone of Climacograptus spiniferus, etc.
	3 Zone of Lasiograptus eucharis, etc.
	2 Zone of Glossograptus quadrimucronatus cornutus, etc.
	1 Zone of Diplograptus amplexicaulis and Corynoides calicularis

Looked at in a general way, these zones would seem to form a progressively overlapping series in the continuous belt of black shale extending from the mouth of the Mohawk to that of the Black river, the oldest zones being in the southeast, at the lower Mohawk, and the youngest in the northwest, at the lower Black river. This series does not, however, express a regular advance of the sea in that direction, but only the migration of the black shale making conditions whatever these were (see p. 76), from the southeast towards the northwest, resulting in a belt of black shale.

Conditions were not by any means as regularly and gradually changing as the continuous belt of black shale would suggest, for there are sufficient irregularities found in the distribution of the horizons to indicate overlap and interlocking of deposits of different ages from different directions, as well as possible tilting, local emergence and the presence of low divides, producing basins about the Precambrian Adirondack mass. Some of these basins have found expression in the diagrammatic section of the Paleozoic formations of the Mohawk valley, by E. O. Ulrich and R. Ruedemann, in New York State Museum Bulletin 162, opposite p. 69, and the Schenectady and Trenton Falls basins have there been specially named. Both appear to be well supported by the great thickness of the Ordovician shales in these regions.

A fuller discussion of the overlapping belts of rocks and of the basins has to be deferred until the zones of the Frankfort and Lorraine formations have been analyzed and traced.

The Frankfort Shale. We have given in a former publication (Ruedemann, 1912, p. 7–15) a brief historical sketch of the Frankfort and a discussion of the beds which in the lower Mohawk valley had before been referred to the Frankfort formation. It was seen there that the term was used by the pioneer geologists of New York, notably Vanuxem, for a thick series of bluish gray argillaceous shales and impure sandstones, into which the black, more calcareous Utica shale passes by very slow gradation. This shale is considered by Vanuxem and Emmons to be contiguous with the Utica shale throughout the Mohawk and Black river valleys, and is described as remarkable for its barrenness in fossils. It was placed with the Lorraine beds as a lower division of the " Hudson River group."

The writer has claimed in Bulletin 162 that the Frankfort shale as exposed at Frankfort contains a faunule that connects the formation with the Utica shale instead of with the Lorraine beds. It consists (revised) of

Climacograptus typicalis (Hall)
Prasopora *sp.*
Orbiculoidea tenuistriata Ulrich
Lingula *sp.*
Leptobolus insignis Hall
Camarotoechia (?) humilis *nov.*
Dalmanella multisecta (Meek)
Dinorthis pectinella (Emmons)
Serpulites gracilis Ruedemann
Geisonoceras *sp.*
Triarthrus eatoni (Hall)
Cryptolithus bellulus (Ulrich)

It was further observed that this typical Frankfort formation has not been found exposed in the lower Mohawk valley, but that the thick formation which there overlies the black Canajoharie shale and has been formerly considered as Frankfort and Lorraine shale, is for the larger part much older (Schenectady beds), and holds, in its uppermost division, where it is approximately equivalent to the Frankfort, an entirely different fauna, and has therefore been distinguished as the Indian Ladder beds. The latter could be exactly correlated with the lower third of the Southgate shale of the Eden group at Cincinnati, and the Frankfort beds at Frankfort correspond, according to Ulrich, to the two middle divisions of the Eden group. In view of the close connection between the Utica and Frankfort beds and faunas, Ulrich has proposed to unite the two under the Eden group, in the Revision of the Paleozoic System.

In the last two summers' work, opportunity offered itself to study the Frankfort section north and northwest of Utica, together with those of the Utica and Lorraine formations.

Spoon creek, branch of Fulmer creek near Mohawk. In the magnificent ravine of Spoon creek, 2 miles east of Fulmer creek, a fine section of Frankfort shale, down to the Utica transition beds, is exposed. Here the Frankfort proved as barren as usual and in spite of careful search by C. A. Hartnagel and the writer, only a few fossils were found, namely:

Climacograptus pygmaeus *nov.*
Leptobolus insignis Hall
Serpulites crassimarginalis Ruedemann
Geisonoceras *sp.*
Small lamellibranch, not identifiable

The Utica-Frankfort transition beds on upper Starch Factory creek near Utica contain the faunule, already reported, p. 32, namely,

Climacograptus typicalis Hall r
Leptobolus insignis Hall r
Camarotoechia (?) humilis *nov.*
Geisonoceras *sp.* r
Triarthrus eatoni (Hall) r

Delta dam, near Rome, N. Y. The largest Frankfort faunule was obtained at the Delta dam, 5 miles north of Rome and probably the westernmost exposure of the Frankfort beds. Here on both sides of the large dam, along the new built road, large exposures were made and great quantities of the shale dumped to build the new road dam across the Mohawk valley. It was found here that the fossils are restricted to thin black bands in the mass of bluish-gray shales and sandstone layers. The faunule consists of

Mastigograptus laevis (Hall) r
Climacograptus pygmaeus *nov.* cc
Climacograptus typicalis Hall c
Leptobolus insignis Hall c
Camarotoechia (?) humilis *nov.*
Serpulites crassimarginalis Ruedemann r
Geisonoceras tenuistriatum frankfortense *nov.* rr
Triarthrus eatoni (Hall) c

Six Mile creek near Rome. The Six Mile creek locality near Rome, famous through the discovery of specimens of Triarthrus eatoni ("T. becki") and Cryptolithus bellulus ("Trinucleus concentricus") with appendages, has, incidentally to the search for these trilobites, furnished a number of other Frankfort shale fossils that are not recorded from other localities. In collections from Six Mile creek, mainly in the United States National Museum, we have found:

Polyplectella mira *nov.*
Mastigograptus laevis (Hall)
Inocaulis arborescens *nov.*
Climacograptus pygmaeus *nov.*
C. typicalis Hall

Arthrostylus tenuis (James)
Lingula progne (Billings)
Leptobolus insignis latus *nov.*
Trematis (?) *sp. cf.* dyeri Miller (fragment)
Camarotoechia (?) humilis *nov.*
Schizocrania filosa (Hall)
Protoscolex giganteus *nov.*
Serpulites
Triarthrus eatoni (Hall)
Cryptolithus bellulus (Ulrich)
Proëtus beecheri *nov.*

Proëtus beecheri, as well as Serpulites intermedius, have also been observed by the writer in Frankfort shale from Holland Patent.

Quaker hill brook opposite Westernville. The Utica section described above from a brook coming from Quaker hill opposite the village of Westernville, continues in this place entirely through the Frankfort shale into the Lorraine. The transition from the Utica shale into the Frankfort is extremely gradual and the 240 feet of Frankfort beds are very barren of fossils.

Most careful collecting has afforded a few specimens each of the following species:

Climacograptus pygmaeus *nov.*
Climacograptus typicalis Hall (narrow specimens approaching C. typicalis posterus)
Glossograptus quadrimucronatus Hall
Leptobolus insignis Hall
Schizocrania filosa Hall
Camarotoechia (?) humilis *nov.*
Triarthrus eatoni (Hall)

A similar section from the Utica through the Frankfort shale into the Lorraine is exposed on the north side of Quaker hill near Hillside (see Utica section, p. 43). This has furnished only Camarotoechia (?) humilis *nov.* and Triarthrus eatoni (Hall)

Along Mill creek, near Turin, about 20 miles north of Northwestern the Frankfort beds have been reduced to no more than 40–50 feet. Here at the upper bridge across the creek, about 300 feet above the Trenton limestone, in Frankfort beds, layers full of Glossograptus quadrimucronatus (typical form) were found. This is not the Utica mutation of Glossograptus quadrimucronatus described by me as Glossograptus quadrimucronatus approximatus, but a coarser form, which has all the characters of the type of the species as described by Hall from the "Utica shale" of Lake St John, and as known from the Hartfell shale of Great Britain and from Sweden. This is immediately followed by the microfauna of the lower Lorraine.

In the fine Whetstone Gulf section the Frankfort beds occupy about 70 feet. They contain:

Climacograptus pygmaeus *nov.*
Climacograptus typicalis posterus *nov.*
Triarthrus eatoni (Hall)

In the Atwater Brook section, the Utica facies is followed by about 70 feet of Frankfort shale. There were found several very fossiliferous bands in the gray shales. They contain:

Glossograptus quadrimucronatus (Hall) (typical form)
Climacograptus typicalis posterus *nov.* c
Climacograptus pygmaeus *nov.* c
Diplograptus nexus *nov.* (layer 8)
Leptobolus insignis Hall r
Camarotoechia (?) humilis *nov.* r
Orthoceras (Geisonoceras). *sp.* c

In the Deer River section the rocks of Frankfort aspect are reduced to less than 70 feet, and contain:

Glossograptus quadrimucronatus (Hall) (typical form)
Climacograptus typicalis posterus *nov.*
Mastigograptus *sp. cf.* simplex (Walcott) (fragment)
Leptobolus insignis Hall
Zygospira modesta (Hall)
Geisonoceras *sp.*
Triarthrus eatoni (Hall)

The Lorraine Gulf section begins with black shale, exposed at the Allendale bridge. This shale has been considered as Utica shale by former authors and collectors, the present one included. We have, however, shown on p. 48 that this locality is some 200 feet above the top of the Trenton limestone and hence, considering the small thickness of the Utica shale in northwestern New York, as shown at the nearby section of Deer river, considerably above the Utica shale. This conclusion is verified by close inspection of the lithic character of the rocks, and by the fauna.

The shale, while prevailingly dark, consists of black bands of argillaceous shale, interbedded with dark bluish-gray shales and thin sandstone bands. The black layers proved very fossiliferous. They afford:

Mastigograptus *cf.* tenuiramosus (Walcott) rr
Climacograptus typicalis posterus *nov.* r
Glossograptus quadrimucronatus (Hall) cc (typical form)
Amplexopora *cf.* petasiformis (Nicholson)
Leptobolus insignis Hall c
Zygospira modesta (Hall) cc
Serpulites *cf.* crassimarginalis Ruedemann rr
Hyolithes *sp.* rr

Clidophorus scitulus (Emmons) *var.* rr (small form)
Geisonoceras tenuistriatum (Hall) cc
Elpe radiata (Ulrich) rr
Triarthrus eatoni (Hall) (large) cc

In a thin sandstone band in the uppermost part of this black shale was found:

Diplograptus nexus *nov.* c

The black and gray shales at the bridge are overlain by barren bluish-gray shales and sandstone which in one band, 10 feet above the black shales, had furnished:

Diplograptus nexus *nov.* c
Leptobolus insignis Hall c
Zygospira modesta (Hall) c
Ctenodonta *sp.* r
Archinacella *sp.* r
Triarthrus eatoni (Hall) c

Summary of the Frankfort sections. The Frankfort beds as a lithologic unit, between the Utica and Lorraine beds, attain their greatest thickness in the Utica basin. At Frankfort the aneroid measurement gives them a thickness of 305 feet to which about 200 feet have to be added on account of the dip. On the Richfield Springs quadrangle, just to the east of the Frankfort region, Hartnagel also estimates the thickness of the Frankfort to be 500 feet. At Westernville, 25 miles northwest of Frankfort, only about 250 feet of Frankfort shales were observed and in the Whetstone gulf and at the Deer river, the northernmost exposure, the thickness does not amount to much more than 70 feet. The Frankfort shale then thins quite regularly northwestward. Westward it passes rapidly under younger formations. It follows from the gas well sections published by Prosser (1900) that the Frankfort shale, like the Utica shale, also thins westward.

Regarding the faunal connections of the Frankfort beds, we have stated in New York State Museum Bulletin 162 that they are with the Utica shale, this inference being based on the very small faunules then known.

It is true the faunules recorded here from the localities immediately north and northwest of Utica and Rome, the Delta dam, Quaker hill, Six Mile creek and Mill creek sections, would seem to corroborate this view, for in their general aspect they consist of Utica forms such as the upper Utica graptolites; Climacograptus pygmaeus, C. typicalis, Glossograptus quadrimucronatus; and of other Utica fossils, as, Leptobolus insignis, Schizocrania filosa, Serpulites crassimarginalis, Geisonoceras tenuistriatum *mut.* frankfortense, Triarthrus eatoni.

The more complete collections of Frankfort fossils especially that which the search for the trilobites with appendages at the Six Mile creek near Rome has furnished as a by-product, leave, however, no doubt that there is present besides the prevailing Utica-stragglers, a distinctly new element in the association that is nowhere seen in the Utica.

We had already recorded in New York State Museum Bulletin 162 the finding of Orbiculoidea tenuistriata Ulrich at the top of the Frankfort shale in the Frankfort section. This is an Economy form in the Cincinnati section.

To this can be added now as forms not known from the Utica shale:

Polyplectella mira *nov.*
Mastigograptus laevis (Hall)
Inocaulis arborescens *nov.*
Arthrostylus tenuis (James)
Lingula progne Billings
Trematis (?) *sp. cf.* dyeri Miller
Serpulites intermedius *nov.*
Protoscolex giganteus *nov.*
Cryptolithus bellulus (Ulrich)
Proëtus beecheri *nov.*

To these should be added as a fossil characteristic of all Frankfort outcrops, although appearing already in the last Utica beds, Camarotoechia (?) humilis *nov.* and two forms that are sufficiently different from the Utica species to be recognized as mutations, namely, Leptobolus insignis latus and Geisonoceras tenuistriatum frankfortense.

It is thus apparent that the Frankfort shale has a distinct biota peculiar to itself, and it is further remarkable that none of these new forms is known from the Whetstone gulf formation. This is probably due to the difference in facies and in physical conditions, as expressed by the fine grain of the Frankfort shale and the general paucity of fossils. They may then be considered as peculiar to the Frankfort facies. This is especially true of Camarotoechia (?) humilis.

On the other hand, we have in Cryptolithus bellulus, another distinct Economy form of the Cincinnati section.

The meager evidence of the Economy age of the Frankfort furnished by these fossils is in full accord with the more important evidence afforded by the resting of the very fossiliferous lower Lorraine beds clearly of Economy age, upon the Frankfort north of Utica and Rome (see Wood creek, Mill creek, Quaker hill sections, postea p. 90).

The fact of the rapid thinning of the Frankfort beds northward, combined with the observation of the appearance of Lorraine shales of equal age with the Frankfort in that direction, is fairly conclusive proof that the Frankfort " facies " merges northward into the lower Lorraine shales, thus disappearing only as a lithologic facies.

There is, however, a further complication produced by two more facts. The first of these is that the Deer River shale wedges in from the north between the Frankfort facies and the Cobourg limestone, and the second is that the northern development of the Frankfort facies, is characterized by Climacograptus typicalis posterus and the typical Glossograptus quadrimucronatus which would connect this Frankfort shale not with the Utica but with the Deer River black shale. Nevertheless, this northern Frankfort shale, is followed by lower Lorraine shale of Economy age, while itself shows evidence of Fulton age. The northern Frankfort is thus not younger than the typical Frankfort, but older and either of later Utica or early Frankfort age. We will for that reason distinguish it as the "Atwater Creek shale." The following diagram would seem to express the relations between these beds:

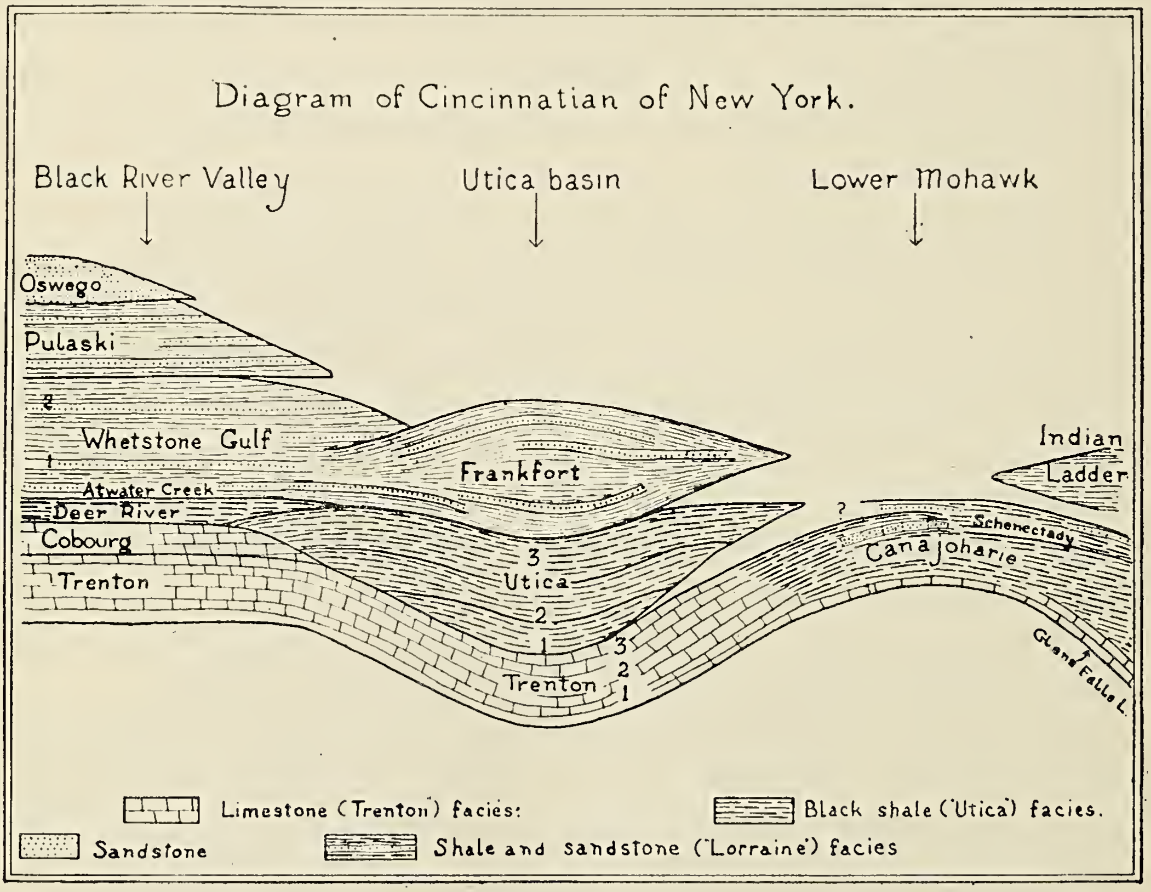

Figure 2

The Frankfort-Economy sea overlapped northward on the Deer river shale and the characteristic graptolites of the Deer river invasion continued to live there in Frankfort time.

In the final report of the first survey, Vanuxem distinguished the Utica shale as a separate unit from the Frankfort shale, and united the latter with the Pulaski shale in the Hudson River group, but as Foerste has pointed out (Foerste, 1916, p. 3), he had no clear knowledge as to where to draw the line between the Frankfort and the Pulaski shales.[1] Emmons in his final report also adopted the term Utica slate for the black shale, but used Lorraine group in place of Hudson River shale, including in this term all the formations from the top of the Ordovician down to the Utica slate as defined by him. The terms "Hudson River group" or "Lorraine group," with the two subdivisions of Pulaski shale and Frankfort shale, since that time were used by the New York State Survey until 1899, when the term Cincinnatian group was adopted by Clarke and Schuchert for the upper division of the Ordovician to comprise the Utica, Frankfort and Pulaski shales as separate stages. This practice has been continued to this day (see Hartnagel, 1912) the term Lorraine being considered a local term for the combined Pulaski and Frankfort shales.

Ulrich (1911) unites under the Frankfort formation the members (McMicken, Southgate and Economy beds) which for some time had been called the Eden beds by various authors, although the term "Eden" as originally proposed by Orton had included all the shales from the top of the Point Pleasant Trenton limestone to the base of the Maysville, hence also the thinning western edge of the "true Utica," as understood by Ulrich at this date and explained below.

For that reason Ulrich has united the Utica and Frankfort as the two subdivisions of the Eden; the Fulton shale representing the Utica in the Cincinnati section. The term "Frankfort" thus applied comprises the lower Lorraine shales underlying the Pulaski. We have, however, seen so far that the Frankfort in the type section is equivalent only to the lower part of this lower Lorraine shale, probably only to the Economy and that the Frankfort " facies " northward goes backward into Fulton time.

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[1] Vanuxem states (*loc. cit.* p. 64) that "fossils are rare in lower part of Frankfort slate, but numerous in upper part where it joins the next series, the Pulaski shale." These fossils are cited from Lee Center and Whidall's quarry near Rome. The latter locality was visited by Professor Foerste and led him to his above-cited conclusion. The section at Lee Center was carefully studied by the present writer and found to begin with the lowest true Lorraine. It is obvious from this that Vanuxem included the lowest still prevailingly shaly portion of the Lorraine, in spite of its Lorraine fauna, in his Frankfort. He cites for this locality: Trimerus delphinocephalus and Pentacrinites hamptonii. The former is probably a confused identification of Isotelus stegops occurring in these beds with the Niagaran Homalonatus delphinocephalus (Green), the latter a Homocrinus. Pentacrinites hamptoni is, according to Bassler, an unrecognized species of Emmons, based on a crinoid plate.

The difficulties arising from the application of the term "Frankfort " to all lower Lorraine shale instead of to the Frankfort " facies " of rocks can not be appropriately discussed until the stages of the lower Lorraine have been established. (See postea p. 147.)

COMPARISON OF THE UTICA WITH THE COLLINGWOOD AND GLOUCESTER SHALES OF CANADA

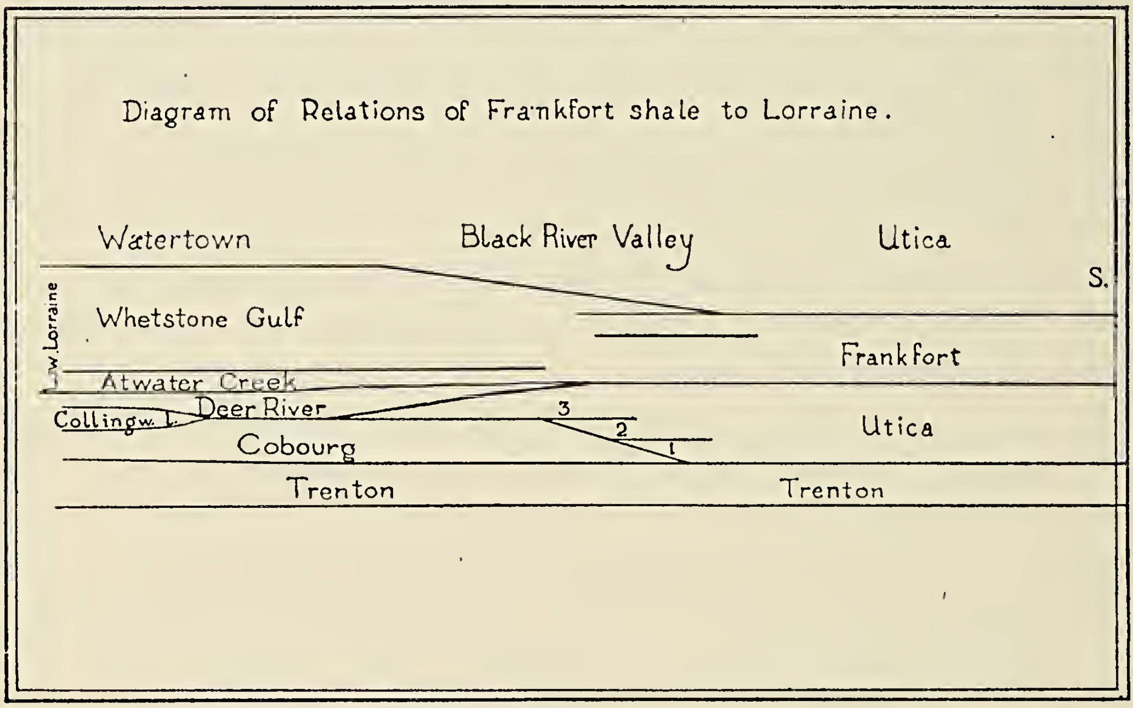

Figure 3

The Collingwood shale was formerly, together with the overlying black shale, correlated with the Utica of New York. It was differentiated by Raymond (1913, p. 144) and described as 25 to 50 feet thick at Ottawa and in southern Ontario, and forming there in lithology a sort of transition between the Trenton limestone and the " Utica " but containing a sufficiently distinct fauna from both. Its most characteristic fossils belong, as pointed out by Raymond to types more common in Europe than in America, as notably its index fossil Ogygites latimarginatus Hall (canadensis Chapman).

The Collingwood shale has been placed by Raymond (1916, p. 257) above the New York Utica and correlated with the Frankfort, the Canadian "Utica" being at the same time distinguished as a separate unit, the Gloucester. On the other hand, Bassler, in the same year (1916, p. 1513 and plate 2) has considered it as equivalent to the upper Trenton. Ulrich (1913, p. 662) has mapped it as an independent late Trenton invasion from the northeast.

Raymond's correlation is clearly based on the fact that the Collingwood in Canada rests upon the Cobourg limestone, which is not present at Trenton falls, but farther northward appears to hold the position of the Utica shale; that of Ulrich and Bassler rests upon the position of the Collingwood below the Canadian "Utica." The Collingwood appears to reach the northwest of New York only in traces and it could for this reason not be placed in our series by direct observation. Certain facts have, however, come to light, which seem to indicate its place in the New York series.

The most important of these is that of the Utica shale at Holland Patent which containing the typical Utica fauna, has turned out to be upper Utica, although it rests directly upon the Trenton limestone. The sharp boundary there observable between the Trenton and Utica marks hence a disconformity and a hiatus in which the lower and middle Utica appear to have been lost in going north from the region in the Mohawk valley where the Trenton and Utica are connected by transitional beds. Assuming — on good grounds — that the Canajoharie shale corresponds to the whole of the "Prasopora beds" or true Trenton, the whole of the missing Utica may be represented by the Rafinesquina deltoidea beds at the top of the Trenton section which Raymond places at the base of his Cobourg beds. This is quite possible if one considers that this middle and lower Utica, in spite of its great thickness, is largely a local swelling up of the formation in a sinking basin. If then the upper Utica is replaced northward by the Cobourg limestone, the Collingwood might be properly considered as post-Utica in age.

There are, however, certain biological facts which can not be made to agree with these purely stratigraphic considerations. One is the appearance of the Gloucester shale fauna in the upper Utica at Holland Patent and in the still younger Atwater creek shale. The well-known typical Utica shale at Holland Patent contains in Triarthrus spinosus and Leptograptus flaccidus, and the superjacent Atwater creek shale in the typical Glossograptus quadrimucronatus the most characteristic fossils of the Gloucester shale. The last two forms are north Atlantic types that are well-known in Europe. They, combined with the aberrant form Triarthrus spinosus seem clearly to place the Gloucester shale into upper Utica time, the shale representing, however, an independent invasion from the North Atlantic where the characteristic fossils of the Gloucester shale had their undoubted metropolis. If, however, the upper Utica shale, at its base, is of the same age as the Gloucester shale of Canada, then the Collingwood is older than the upper Utica. This inference seems to us also to be borne out by other fossil evidence, such as the abundance of Primitiella unicornis Ulrich, or an extremely closely related ostracod, that species being a Fulton and upper Canajoharie species, and the appearance of still other types such as Conularia trentonensis *mut.* and Lingula trentonensis (besides Lingula progne Billings) in the Canadian shale. It then seemed proper to infer that the Collingwood shale also falls within the hiatus marked by the disconformity at Holland Patent and lies between the Cobourg limestone and the upper Utica, the Cobourg limestone being equivalent only to the lower and middle Utica.

A few days after we had reached the conclusion of the position of the Collingwood shale on conjectural grounds, a slab of this shale came to hand which besides the characteristic Ogygites latimarginatus and other fossils, also contained graptolites which were easily recognized as Glossograptus quadrimucronatus and Climacograptus pygmaeus, thus proving by direct evidence that the Collingwood shale still falls within the boundaries of the upper or third zone of the Utica shale. It is a corollary of this conclusion that the Collingwood shale can not be represented in either the Deer river or Atwater shale of the Black river valley but is older than either. We must rather see in them late stages of the Gloucester invasion.

PALEOGEOGRAPHY OF THE UTICA SHALE AND ASSOCIATED FORMATIONS

As long as the black shales of the Mohawk river, Black river, Hudson river and Champlain valleys were considered as of Utica age, it seemed a simple matter to trace this formation northeast to Anticosti and Lake St John and to the Atlantic, and likewise southeast through the Appalachian valley. Toward the west its top was identified in the Fulton beds about Cincinnati and thence northwestward was traced mainly through well-sections to the islands in Lake Huron. The wide extension given formerly to the Utica is well expressed in the comprehensive descriptions of this formation by Walcott (1883) and Ami (1892) and has also been brought out in the first paleogeographic map of the Utica by Ulrich and Schuchert. (Schuchert, 1910, pl. 60.)

As in the case of other, formerly broadly conceived formations, recent investigations have shown that the "Utica" formation is composed of several members of different age, each representing a different invasion. Thus the writer (Ruedemann, 1912) has demonstrated that the black shale belt of the lower Mohawk and upper Hudson valleys is composed of rocks of Trenton age, the Canajoharie shale, and Raymond (1913, p. 144, 1914) has separated the alternating shale and limestone with Ogygites canadensis in the lower part of the Canadian Utica as Collingwood formation from the rest.

Ulrich (1911, p. 372, 521) recognized the fact that while the Utica transgression extended from New York as far as Kentucky, it is only the last Utica stage that reached the western limits, and further that it is not certain whether the true Utica is represented in the Martinsburg shale in the Appalachian valley. On the Mercersburg-Chambersberg quadrangle, for instance, Ulrich (in Stose, 1909, p. 10) found only the Canajoharie and post-Utica formations represented in the Martinsburg shale.

These new observations have already found their cartographic expression in the late paleogeographic charts of Ulrich (1913, map III) and Schuchert (1915, pl. 8, p. 635) where the Utica sea is greatly restricted. Ulrich's chart separates the Collingwood and Utica invasions, bringing in the former from the strait of Belle Isle by way of Anticosti, through the St Lawrence valley and extending it as a narrow arm of the sea as far west as the Manitoulin Islands. The Utica, on the other hand, forms a small subtriangular inland sea near the middle Atlantic coast, having its inlet in the Appalachian region (based on the Martinsburg and Reedsville shales), its base extending as far west as western Kentucky and its apex in northern New York at the Adirondack massive.[1] Schuchert's chart combines the Utica and Eden formations and the sea appears as a wedge-shaped embayment, entering from the Gulf of Mexico and extending to the New York exposures in the east and the Georgian bay exposures in the west.

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[1] In Bassler's Cambrian and Ordovician of Maryland (1919, fig. 24) the two invasions are again united by Ulrich. We have presented here evidence of, at least, brief connections of the Utica and Collingwood-Gloucester seas.

Ulrich, in a letter, describes the present status of the paleogeographic problems of the Utica as follows:

> Many of these paleogeographic problems are exceedingly difficult; and the Utica one, as I have long felt, is one of the worst. From which direction did the Utica fauna invade? I think you are right in throwing out the north and northeast possibilities. The northwest and west may likewise be disregarded. All then that remains is the Gulf of Mexico and the Middle Atlantic.
>
> Reviewing known deposits of Utica age, we find that they are confined to a subtriangular area bounded by New York on the northeast, by Indiana and Central Kentucky on the west and the western edge of the Appalachian valley on the southeast. We know from observation of outcrops and from deep well records that the Utica pinches out to the north and to the west. On the southeast side we know that thick deposits of this age occur in the western bands of the Appalachian folds. So far as I know the Utica is absent entirely in the eastern folds. Granting, or perhaps I should say, assuming, that absence of beds implies nondeposition because of emergence at the time, the only pathway remaining to connect this inland Utica sea with the permanent oceanic basin is one lying buried beneath the later rocks of the Allegheny plateau. If this is the pathway it must have been a very narrow one — in fact, a channel less than 30 miles wide where it crosses the southern border of Tennessee.
>
> When I made the paleogeographic maps published in my International Congress paper, I carefully considered the Utica invasion and, as you may see by consulting map III, I finally decided against the Allegheny-Cumberland plateau channel and drew one directly across the Piedmont area to the Atlantic between Chesapeake and Delaware bays. In southern Pennsylvania the shale mass (Martinsburg) which is supposed to include the Utica stage actually transgresses farther eastward in the Appalachian folds than elsewhere; and there are great masses of schists to the east of these that may well represent the metamorphosed seaward continuation of the Martinsburg.

As far as the limited territory of our State is concerned, the general problems of the Utica resolve themselves into the questions: How far does the Utica extend east (in Hudson and Mohawk valleys), northeast in Champlain valley, and northwest in Black river valley? and, does the Collingwood shale enter our State?

The true Utica shale is not exposed in the Hudson river valley. The black graptolite shales which formerly were referred to the Utica, as for example, the shale at the Rural Cemetery near Albany (see New York State Museum Memoir 11, p. 37), are now known to belong to the Canajoharie shale.

The northern extension of the shale of the Hudson valley is formed by the Champlain basin. Here the black shales exposed in small scattered outcrops on the west side of the lake (Ticonderoga, Rouses Point) and more continuously on the Vermont side (Panton, Burlington, North Hero) have been currently considered and mapped as Utica shale. As set forth in an earlier paper, there is no true Utica shale in the Champlain valley, but all the black and gray shales there are of Trenton age.

The Utica shale does not reach the lower Mohawk valley as such, but the question has been raised by Raymond (1916, p. 250) whether the Schenectady beds, correlated by the writer with the upper Trenton, should not be considered as of Utica and Frankfort age.

Our evidence regarding the age of the Schenectady beds is twofold, first their stratigraphic position, and second the fauna. The Schenectady beds (shales and sandstones of Lorraine aspect) rest upon the Canajoharie shale, which is considered by us as of lower and, in part, middle Trenton age and they are in turn overlain by the Indian Ladder beds which by their fauna were proven to correspond to the Southgate division of the Eden shale. It is therefore true that the Schenectady beds occupy stratigraphically the time interval between the middle Trenton and the Eden, and would be partly of Trenton and partly of Utica age, unless there is a large hiatus at their top between them and the Indian Ladder beds. Regarding the faunal aspect we have stated (*op. cit.* p. 49):

> The dominant elements of this large fauna are certain Canajoharie and Utica shale species on one hand, and the eurypterids on the other. The former elements are the species of Mastigograptus, Diplograptus vespertinus, Climacograptus typicalis, Lasiograptus eucharis, Leptobolus insignis, Trocholites ammonius and Triarthrus becki. These are also the most frequent species, and the entire fauna receives thereby a distinct Canajoharie-Utica aspect. But we also note in the congeries of forms a number of species that are not observed in either the Canajoharie or the Utica, but are known only from the Trenton. Such species are Lingula rectilateralis, Conularia trentonensis, Spyroceras bilineatum, Cryptolithus tesselatus, Eurychilina. It is mainly the evidence from these fossils that indicates the Trenton age of the Schenectady formation.

To these should be added Climacograptus spiniferus (*op. cit.* p. 44), a graptolite that distinctly points to lower horizons. With these occur numerous eurypterids and other forms which give the Schenectady fauna a character of its own, and together with the great thickness and northward extension of the Schenectady beds, were taken by us to indicate that the beds were deposited in a sinking trough more or less separated from the more western sea.

We have considered the Utica aspect of the fauna as largely due to the shaly facies of the formation, since some Utica species, appear already in the lower Canajoharie shale, of early Trenton age, and again with the first shaly intercalations in the upper Trenton limestone.

Closer study of these fossils of Utica aspect in the Schenectady, Canajoharie and Snake Hill shales has brought out interesting facts which show that, notwithstanding their similar aspect, the most important species are not identical in these Trenton shales and the Utica shale. We will here mention only the two most important cases, those of the occurrences of Triarthrus becki and Cryptolithus tesselatus (Trinucleus concentricus auct.) in both the Trenton and Utica shales.

The Triathrus of the Schenectady-Canajoharie, Snake Hill shales has been found to be the true T. becki of Green, whose type came from the Snake Hill shale at Cohoes falls, Cohoes, N. Y. We have traced this species now through the Trenton shales of the Hudson and lower Mohawk valleys and the Champlain valley to the supposed Utica at Rouses Point.

The Triarthrus of the Utica shale is T. eatoni (Hall) once distinguished by Hall (see under T. eatoni pt 2), but later again withdrawn. This is a good species and restricted to the Utica, Frankfort and lower Lorraine (Whetstone Gulf shale) and the Collingwood and Gloucester shales in Canada.

Equally interesting is the case of Cryptolithus tesselatus. It is stated by Raymond (1916) that this species is restricted to well-marked horizons, and that its occurrence in the Schenectady beds is indicative of their Utica age; since Cryptolithus tesselatus only occurs in the lower Trenton and the Utica. Closer comparison of the forms here involved has, however, brought out the interesting fact that the Cryptolithus of the Schenectady beds is the original Cryptolithus tesselatus of Green, whose type came from the canal at Waterford, and that this is the Trenton species, which is well distinguished from the Frankfort and lower Lorraine form C. bellulus Ulrich. The supposed occurrence in the Utica shale turns out to be one in the Frankfort at Six Mile creek near Rome, and to belong in the lower Lorraine formation. The occurrence of Cryptolithus in the Schenectady beds is hence evidence pointing in the opposite direction as has been supposed.[1]

Both trilobites, Triarthrus becki and Cryptolithus tesselatus while apparently linking the shale in the Hudson river with the Utica, in reality help to correlate the former with the Trenton. It is obviously the genus in this case, not the species, that prefers the shaly facies.

Considering both the stratigraphic and faunistic facts known of the Schenectady beds, we are sure that they in the greater part correspond to the upper Trenton, but also consider it possible that they may extend into Utica age. In that case the Utica sea would have extended farther east than the typical Utica shale would indicate, and have entered a fore-deep of the Taconic folds that may have led it northward into the Champlain sea to an unknown extent and southward along the Appalachian geosyncline. The observations of Ulrich and the writer, however, show the " Utica " of the Champlain valley to be of Trenton age only.

Northwestward the Utica thins in the Black river valley until at the Deer river only Deer River shale seems to be present.

In Ontario the Collingwood, which rests on the upper Cobourg, is of the age of the Utica, but the Collingwood does not come in contact with the Utica of New York and the Collingwood and Utica seas do not seem to have been united at any time. Resting upon it Raymond (1913, p. 144) reports 200–300 feet of Utica. The fauna of this brown and black carbonaceous shale contains besides Climacograptus typicalis, Leptobolus insignis and Triarthrus eatoni such forms as Climacograptus bicornis, (=spiniferus(?)) Triarthrus spinosus and Triarthrus glaber. Raymond (1916, p. 255) has proposed the name "Gloucester formation" for these beds and cited as characteristic fossils Triarthrus spinosus, T. becki, T. glaber, Leptograptus annectans, Glossograptus quadri-

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[1] Ulrich's exhaustive comparisons of the various forms of Cryptolithus have brought out clearly distinguishable and recognizable invasions from New York to Virginia and Cincinnati.

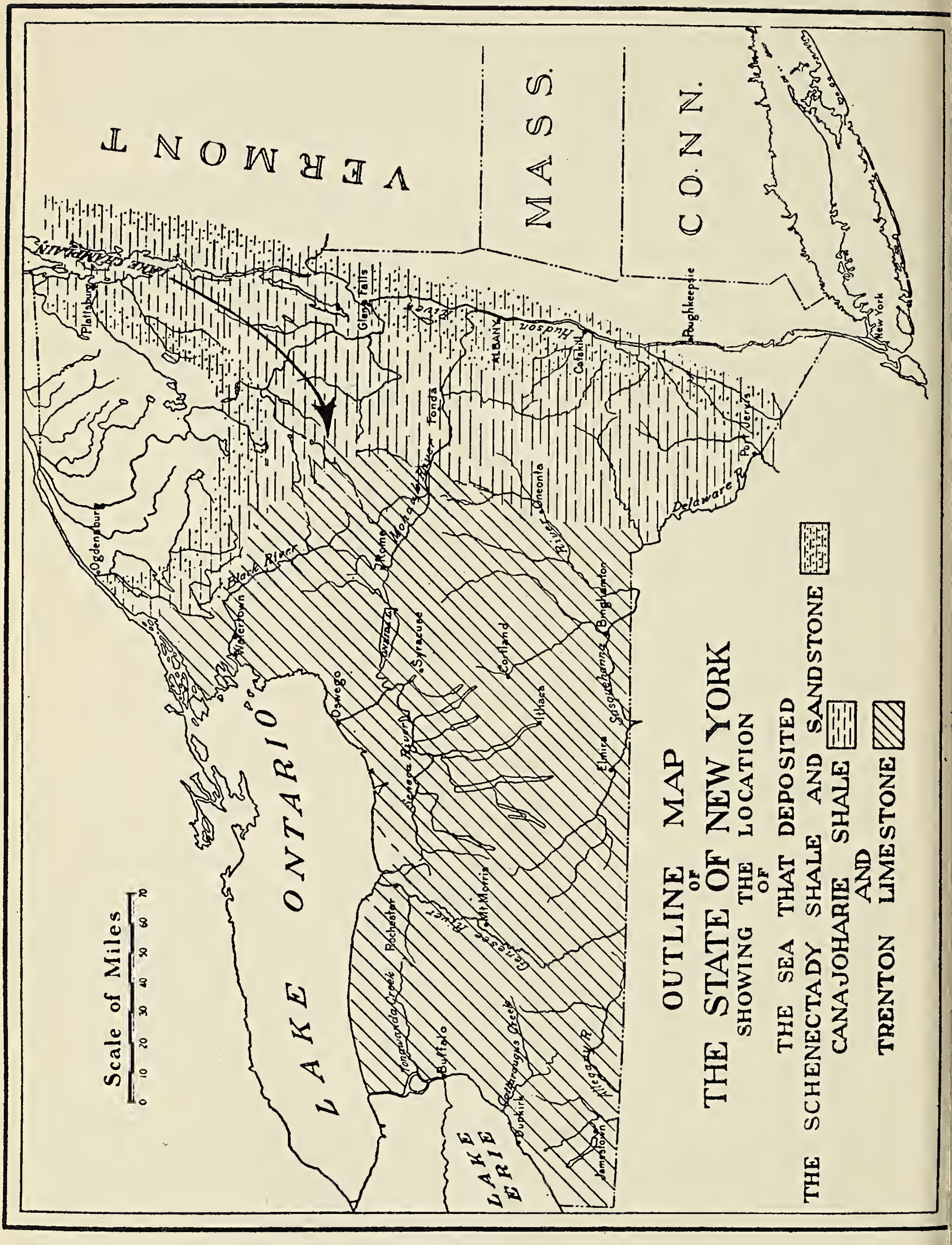
VERMONT
MASS.
CONN.
LAKE CHAMPLAIN
Plattsburg
Glens Falls
ALBANY
Hudson
Catskill
Poughkeepsie
New York
Port Jervis
Delaware R.
Fonda
Oneonta
River
Mohawk River
Rome
Oneida
Syracuse
Cortland
Binghamton
Susquehanna
Ithaca
Elmira
Ogdensburg
Watertown
Black River
Oswego
Seneca River
LAKE ONTARIO
Rochester
Mt. Morris
Genesee River
Tonawanda Creek
Buffalo
Cattaraugus Creek
Dunkirk
Jamestown
Allegany R.
LAKE ERIE
Scale of Miles
0 10 20 30 40 50 60 70
OUTLINE MAP
OF
THE STATE OF NEW YORK
SHOWING THE LOCATION
OF
THE SEA THAT DEPOSITED
THE SCHENECTADY SHALE AND SANDSTONE
CANAJOHARIE SHALE
AND
TRENTON LIMESTONE

Figure 4

mucronatus. We have presented evidence in another place that some of the most characteristic Gloucester shale fossils are found — very rarely indeed — in the upper Utica shale of New York and that there existed but temporary connection between the northern Gloucester and the more southern Utica seas. We have further shown that the Deer River formation which appears in the Black river valley and thins out southward, is probably a late stage of the Gloucester and younger than the Utica. Westward the Utica thins out toward Kentucky. There would then remain by exclusion only the south or southeast, as the possible permanent connection of the Utica sea with the Atlantic basin.

The best evidence of connection with the Atlantic basin is seen in the sudden incursions of typical North Atlantic graptolites, of forms that led a planktonic — or pseudoplanktonic — existence in the Atlantic reservoir, as proven by their range eastward to Great Britain and Scandinavia. Some of those, with longer geologic range, such as Dicellograptus nicholsoni, appear repeatedly, sometimes as rare fossils, as in the Canajoharie and Snake Hill, and then again in great abundance in the middle Utica. Other long-lived forms like Glossograptus quadrimucronatus appear in new mutations with every new incursion. Others, notably Pleurograptus linearis and Leptograptus flaccidus appear but once, in a narrow horizon, as if some specially favorable condition, such as unusually strong currents, had brought them into the epicontinental sea from the Atlantic basin.

In an earlier paper, (Ruedemann, 1897) the writer had inferred that graptolite rhabdosomes, Endoceras shells and other evidence pointed to a current running from north 70° east or a northeast-east direction in the sea that deposited the black shales of the Mohawk valley, then considered to be all of Utica age. It now appears that some of these shales showing that prevailing direction of the fossils are of Trenton age (Canajoharie) and others of Utica age. The more remarkable, then, is the constancy of this direction of the current phenomena in shales of such different age. In the Canajoharie shales the change from shale to limestone westward indicates the source of the black mud in the east and a movement of the water toward west. It is probable, however, that the southward slope of the Adirondack plateau that was not fully covered by either the Trenton or the Utica sea had much to do with the southwestward movement of the waters, either in normal or in tide

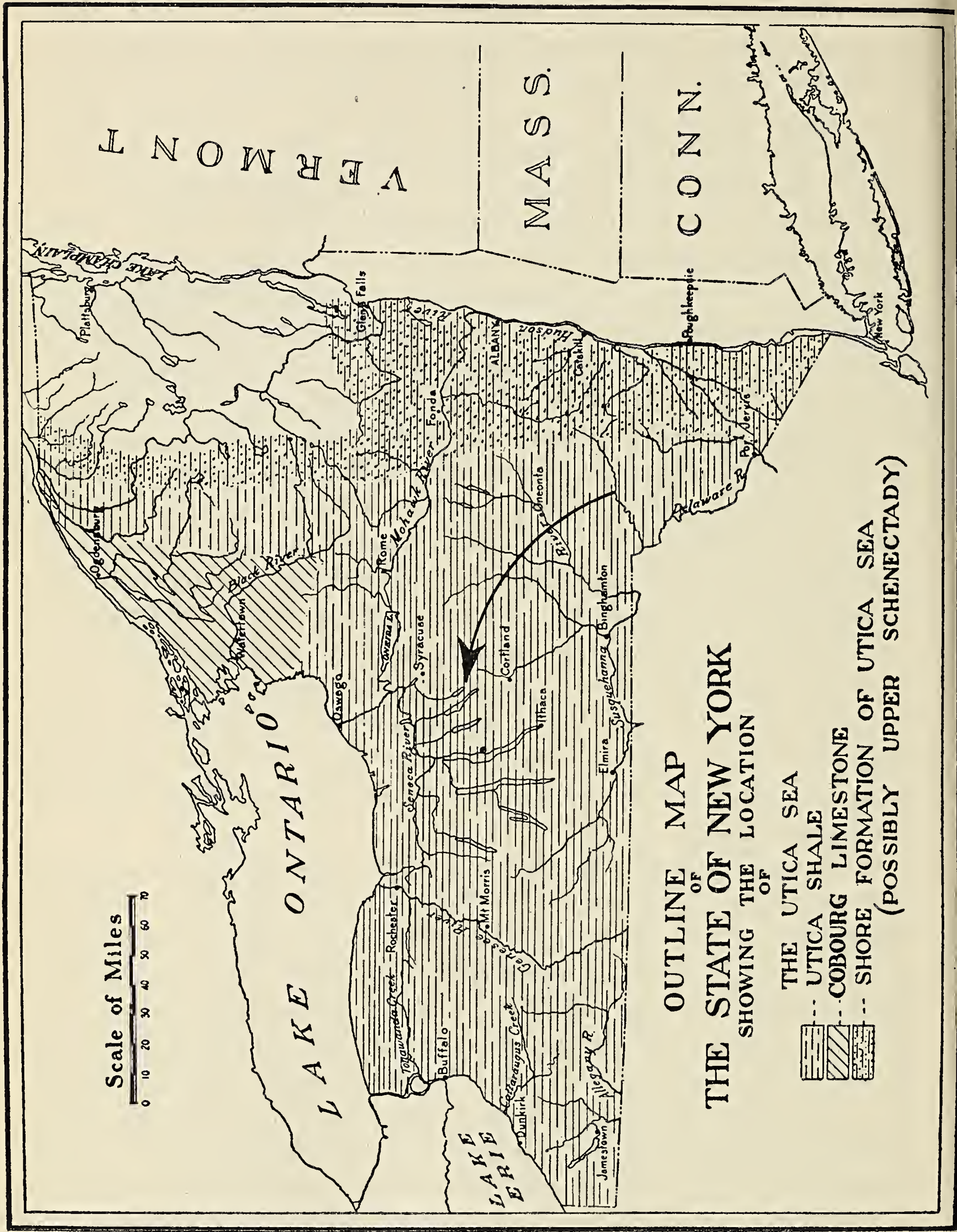
OUTLINE MAP
OF
THE STATE OF NEW YORK
SHOWING THE LOCATION
OF
THE UTICA SEA
▥ .. UTICA SHALE
▨ .. COBOURG LIMESTONE
▦ .. SHORE FORMATION OF UTICA SEA
(POSSIBLY UPPER SCHENECTADY)
Scale of Miles
0 10 20 30 40 50 60 70
VERMONT
MASS.
CONN.
LAKE CHAMPLAIN
Plattsburg
Glens Falls
Hudson R.
ALBANY
Catskill
Poughkeepsie
New York
Port Jervis
Delaware R.
Oneonta
River
Binghamton
Susquehanna
Elmira
Ithaca
Cortland
Syracuse
Oneida L.
Rome
Mohawk River
Fonda
Black River
Watertown
Ogdensburg
Oswego
LAKE ONTARIO
Seneca River
Rochester
Mt Morris
Genesee R.
Tonawanda Creek
Buffalo
Cattaraugus Creek
Dunkirk
LAKE ERIE
Jamestown
Allegany R.

Figure 5

currents, over this slope in both periods. In the case of the Canajoharie shale which has furnished most of the evidence it is well conceivable that a strong ocean current came down east of the present Adirondack plateau, through the Champlain region and swept over the southeast slope of this ancient massive, gathering the silt brought down by the rivers and distributing it along the coast; while in the case of the Utica shale it may have been only the northernmost loop of a circulatory current sweeping around the shore of this limited epicontinental sea, or again the influence of a large river flowing from the northeast into that sea.

ORIGIN OF BLACK SHALES OF CINCINNATIAN

The black shale condition appears earliest in the east, not only in New York in the Mohawk valley and in the Champlain basin, but also farther south in the Martinsburg shale, extending in the Appalachian region from New Jersey to Virginia. It gradually progresses thence west and southwestward. As the alternations of limestone and black shale in the "Dolgeville beds," a transition zone, indicate, the difference consisted solely in the absence or scarcity of terrigenous mud in the Trenton sea and its overwhelming influx in the Utica and Canajoharie waters; first in a succession of short invasions, after each of which the former, congenial lime-making condition of the Trenton sea was restored with its flourishing corals, bryozoans, brachiopods and other animals that require purer water for their existence. Every black shale influx brought with it the graptolites and a characteristic black shale faunule.

The question has been much debated whether these black shales required deep or shallow water for their deposition, whether they were deposited in open or closed basins, etc. The evidence from their gradual replacing by alternation the limestone making conditions of the Trenton sea with its abundance of life is clearly that they were deposited in the same epicontinental sea and at the same depth as the limestone, but that conditions had arisen which produced the influx of great masses of mud in the east pointing to an eastern source of the black mud. This is to be sought in the elevated region to the east (Taconia of Schuchert), where a sufficient drainage had developed to supply the eastern marginal sea with the terrigenous mud which was picked up by circulatory currents of the sea and gradually spread westward in ever thinning layers. The presence of such currents has been suggested before by the writer (Ruedemann, 1897).

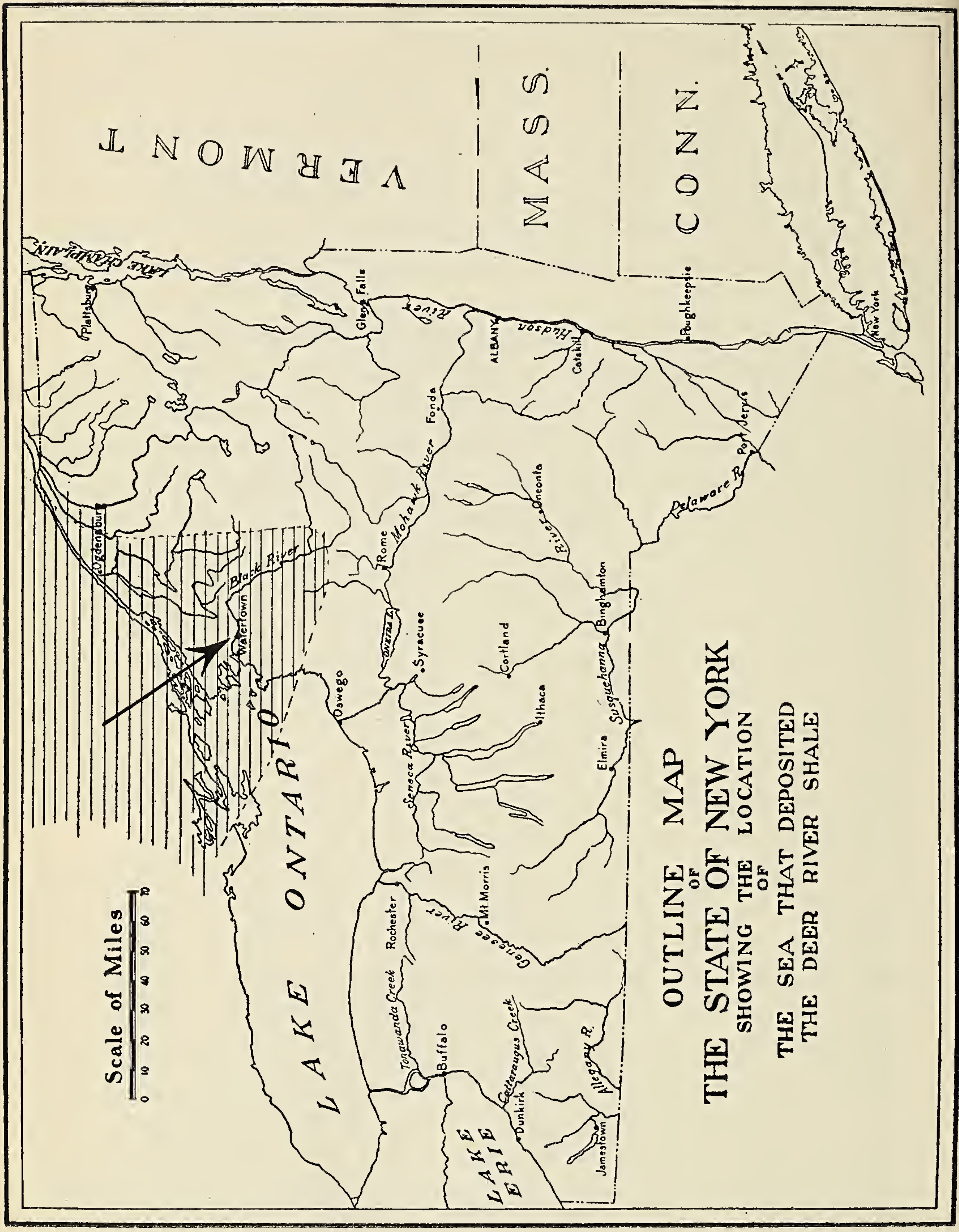
OUTLINE MAP
OF
THE STATE OF NEW YORK
SHOWING THE LOCATION
OF
THE SEA THAT DEPOSITED
THE DEER RIVER SHALE
Scale of Miles
0 10 20 30 40 50 60 70
VERMONT
MASS.
CONN.
LAKE CHAMPLAIN
LAKE ONTARIO
LAKE ERIE
Plattsburg
Ogdensburg
Watertown
Black River
Glens Falls
Hudson River
ALBANY
Catskill
Poughkeepsie
New York
Fonda
Mohawk River
Rome
Oneida L.
Syracuse
Oswego
Seneca River
Cortland
Ithaca
Oneonta
River
Binghamton
Susquehanna
Elmira
Delaware R.
Port Jervis
Rochester
Mt Morris
Genesee River
Tonawanda Creek
Buffalo
Cattaraugus Creek
Dunkirk
Allegany R.
Jamestown

Figure 6

The fact that the black mud that formed the Utica, Canajoharie and Deer River beds, was of very fine texture and that sandstone and conglomerate beds are absent, and further the observation that the black shale of these formations is replaced shoreward by the Schenectady beds, that is, shales and intercalated sandstones, would indicate that these black shales are the result of the deposition of mud that was carried out to sea considerably beyond the littoral zone, and also that it was deposited in relatively quiet water. There is, to my knowledge, never any sign of ripple-mark, sun-cracks, or cross bedding in them, while these features are observable in the Schenectady and Lorraine beds. The relative gentleness of the currents is attested to by the fact that they were not able to keep the delicate graptolite branches and empty cephalopod shells in suspension, but only arranged them in parallel fashion on the sea bottom (see Ruedemann, 1897).

In Utica time the black shale deposition had wandered far enough westward, along the southern slope of Adirondackia to bring the black shale into the Trenton basin, where now 700–800 feet of that shale accumulated, while farther east in another basinlike depression, but in marine connection with it, the Schenectady beds may have still accumulated. The fact that at least three graptolite zones are well developed in the Utica shale, warrants the inference that the latter is probably not the result of such very rapid deposition in a sinking local basin, as would seem to be suggested by the rapid thinning of the formation north and eastward.

As one goes north into the Black river region, the Utica shale dwindles rapidly and a limestone formation, the Cobourg limestone, of younger age than the Trenton of the Trenton section takes its place, to be overlain by a relatively thin black shale formation, the Deer River, which, however, apparently wedges in from the north; and this is followed by the black and gray shales of the Atwater Creek member representing the last Utica stage. It thus appears that the Adirondack mass, although wholly or nearly wholly submerged during Utica time (see Ruedemann, 1898; Cushing, 1905, p. 394)[1] still acted as a barrier of sufficient influence to protect, in earlier Utica time, the submarginal area at its west side from being overwhelmed by the black mud-carrying current, the latter being deflected southwestward.

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[1] Cushing, while agreeing with the writer as to the more or less complete submergence during Utica time would place whatever land remained along the southern margin of the Adirondack region.

The Deer River shale was deposited on the northwest side of the Adirondack mass in an embayment extending southward from the Gloucester sea in Canada; while the Atwater Creek beds, black and gray shales, were again deposited in the eastern marginal region of the Eden sea. All this detritus was probably derived directly from the low northern Adirondack land. Likewise the Frankfort apparently derived a large part of its shale and sand from the southern and southwestern portion of the Adirondack peninsula that was jutting out from the eastern land.

Black shale is still of quite common occurrence in the first Lorraine zone, of Economy age, especially in the region north of Rome, or southwest of the Adirondack peninsula, and also in the Lorraine gulf.

While we have seen so far that the black shale-forming condition appeared first, in early Trenton time, east of the Adirondack mass, especially southeast, but also in the Champlain basin; it gradually spread around this land mass and disappeared last on the west side with the lowest Whetstone Gulf beds. It is everywhere wedged in between the preceding limestone making condition, and the following one producing coarse detritus and gray shales. In certain, basinlike depressions, like that about Utica, great thicknesses of the black shale accumulated. There is further good evidence that the black shale was by water circulation carried westward and had an eastern origin, on the eastern marginal land Taconia of the continent (approximately comprising the present New England). There still remains the much mooted problem of the conditions that controlled the origin of this black shale, that is so important a constituent of our Cincinnatian rocks, and especially that of the origin of the graptolite shale.

This problem has been fully discussed by Ulrich (1911, p. 358) who writes: " Black shale deposition took place under varying conditions of depth and degrees of inclosure," and adds:

> We find similar black muds forming today in stagnant depths of an isolated Black sea, and in Paleozoic ages they were deposited in shallow or perhaps comparatively deep channels with evidently perfect circulation as well as in broad shallow pans in which, except at times when they were abundantly peopled by certain kinds of marine animals, circulation may have been very sluggish and imperfect.

The black color is undoubtedly due to fouling of vegetable material and probably partly also of graptolitic detritus in many of the earlier shales. Ulrich is inclined to consider cool climates as a possible cause, although he does not find the factor satisfactory as a general explanation.

From still more recent contributions to the discussion by Twenhofel (191), Grabau (1913, p. 667, 674), Schuchert (1915, p. 493; 1915, p. 269) and O'Connell (1917), it appears that black shale forms today in quiet bays of inland seas with foul bottom, in the embayments between the mouths of a delta (O'Connell) and between islands, as around Oesel (Twenhofel), in nearly enclosed seas, as the Black sea, on the lee side of a submerged ridge or bank or the edge of the continental plateau (Grabau, p. 673) and in the dead grounds that are formed where the prevailing winds are strong toward the land, whereby a marked undertow is formed that sweeps the bottom clear of deposits and of the organic products of decomposition from the abundant life of the littoral seas. This material gathers in the currentless, deeper depressions of the sea and accumulates as black mud (Schuchert, 1915, p. 494).

While Schuchert, in his latest work, points out that the Black sea condition, once thought to explain all black shale deposition, is an exceptional example, perhaps applicable, among a few other examples, only to the Kupferschiefer of the Permian and the Liassic beds with Posidonomya bronni in Europe and the Upper Devonian and the Chattanooga black shale of North America, Grabau would assign to the last an origin in a seashore delta and O'Connell would generalize this view to such an extent as to include also the graptolite shales, which Grabau (1913, p. 674) before had attributed to deposition by ocean currents on the ocean floor under their pathway.

There is thus a multiplicity of factors assigned to the origin of black shale, all of which have as general underlying cause a certain degree of stagnation due to incomplete circulation; this stagnation preventing both the oxidation of the organic detritus and the development of bottom life.

In a consideration of the conditions under which the graptolitiferous shales of the Canajoharie, Utica, Deer River and Atwater Creek formations, with which we are here mainly concerned, were formed, it is necessary to distinguish between those black shales, which uniformly compose formations of considerable thickness, as the Utica shale, and the sporadic black shale intercalations in the Schaghticoke, Deep Kill, Normanskill, Snake Hill and Schenectady beds, which are principally composed of sandstone, grit, limestone and conglomeratic strata in masses of prevailingly gray, red and green shales. There is another difference between these two groups of graptolite shales which to us seems highly significant. While the first group of thick black shale formations contains besides the abundant graptolites numerous other organisms, mostly small invertebrates (sponges, worms, few brachiopods, pelecypods, few gastropods, cephalopods, trilobites and eurypterids), the second group of black shales is strikingly barren of fossils other than graptolites. The Schaghticoke shale has furnished only a few sponge spicules and a small brachiopod; the Deep Kill shale a worm (Serpulites interrogans) and two gigantic, thin-shelled brachiopods (Lingula quebecensis, Eunoa accola), both only in few specimens and probably of pelagic habitat; the Normanskill shale only a few small brachiopods (Paterula amii, Schizotreta papilliformis, Leptobolus walcotti), a sponge (Graptospongia pusilla), a few small crustaceans (Caryocaris wrightii and C. curvilatus) and finally the eurypterids, described by Clarke and Ruedemann from Catskill, N. Y. None of these biota of the graptolite shales is found in the associated limestones or conglomerates.

An interesting light is thrown on the restriction that organic life suffered on the bottom of the shale-depositing sea in contrast to more favored regions or to the plankton and pseudoplankton by the occurrence in the shale of fragments of seaweeds and pieces of test of eurypterids covered with multitudes of fossils seen only through such a fortunate accident of preservation. We have before us a slab of black Utica shale from Holland Patent covered with drifted and contorted strands of seaweeds that is completely beset with minute brachiopod shells, among which species of Rafinesquina, Lingula, Leptobolus and Paterula may be seen, all too small (.5 mm) and indistinct to allow elaboration of their specific characters even if they are not only early growth-stages. They serve, however, to show what abundance of marine life existed in other (higher) parts of the sea while these barren black shales were deposited. On a patch of eurypterid skin, from the same horizon and locality, not over one-half a square inch in size, there were counted over fifty specimens of a new Schizambon (minutus), not a single specimen of which species was noticed anywhere else in the shale. This patch also points to a neighboring region of more luxuriant life from which this fragment was carried into the depths of the Utica basin.

The Schaghticoke, Deep Kill and Normanskill shale can all three be shown to have been deposited in long narrow troughs running in the direction and region of the later system of Appalachian folds. It was thought for a time, that there might have existed in these troughs the Black sea conditions mentioned above, but it is now generally recognized that the presence of the pelagic graptolites demonstrates the existence of a circulation and the access of marine currents to the troughs (Ruedemann, 1911, Ulrich, 1911). But the absence of other animal life from the shales, sandstones and limestones of the Schaghticoke, Deep Kill and Normanskill beds, which contain the most typical and profusely filled graptolite shales, is sufficient proof that we have to do with dead grounds of some kind. This conclusion is strongly corroborated by the frequent presence of layers with pyritized graptolites, especially in the Deep Kill shale, and also in the Normanskill shale.

This combination of a circulation bringing in the planktonic graptolites and of dead grounds at the bottom suggests to us troughs with free egress and ingress of the sea, but controlled by submarine barriers, such as the one in the Strait of Gibraltar, which, while allowing the entrance of oceanic plankton and a horizontal circulation in the Mediterranean, yet causes the deeper reaches of the basin to be dead on account of the absence of a sufficient vertical circulation and the resulting lack of oxygen, the temperature being uniform from the level of the barrier to the bottom.

It is then possible that these dead grounds were due to a barrier that shut off the deeper parts of the troughs from circulation, or to cold climate, or as O'Connell asserts, to impounding of waters in the shallow bayous and embayments at the mouth of delta-forming rivers. In the latter case the black mud would be derived from a river that flows from a land with moist climate and a rich vegetation, such as the Mississippi or Ganges rivers are today.

Regarding the hypothesis that a colder climate might be in part responsible for the lack of oxidation in the deeper water and for the pauperity of the fauna, Schuchert remarks that black muds today are more liable to form in warmer climates, because nearer to the poles the cold water in sinking to the bottom would provide some form of circulation. It is here, however, to be remembered that the black graptolite shales and other shallow epicontinental black shale deposits were not laid down under oceanic conditions. Regarding the view, advanced by Grabau and O'Connell that the black graptolite shales, like most black shales, are deposited between the mouths of delta-building rivers, it appears that narrow strips, like that of the Normanskill shale, extending continuously from the lower St Lawrence valley through Vermont, New York and the Appalachian region to Alabama would require an impossibly long series of adjoining deltas and that further these graptolite faunas can not be traced westward into the open sea formations, whence they would have to be supposed to have come under that hypothesis, but that, on the contrary, Ulrich and Schuchert's hypothesis of the existence of long troughs in this region seems very competent to explain all phenomena.

There is found also intrinsic evidence in the comparison of the rocks themselves that militates against the assumption of a warm, moist climate sufficient to supply the vegetable material to the rivers to produce the black mud. This evidence rests in the fact that much of the rock, especially in the Normanskill beds, is a rather coarse sandstone, the "Hudson grit" (see Dale, 1899, p. 187) approaching in character an arkose. This rock consists under the microscope of "angular grains of quartz, orthoclase, plagioclase, and scales of muscovite, probably clastic." "The cement," the same author states "contains not a little carbonaceous matter, secondary calcite, and pyrite. In the more easterly Ordovician areas the cement is quite sericitic, and the feldspar is partially sericitized, but in other places, and along the Hudson, in Rensselaer county, the amount of sericite in the cement is small." "The Hudson grits are interbedded and associated with black slates and with graptolite shales" (*ibid.* p. 188). I have before me slabs of this grit from the Normanskill at Albany, covered with graptolites on their surfaces. The presumption, according to Grabau and O'Connell, would then be that these grits are of the same origin as the black mud, that is, brought down by the rivers in time of floods, for there are no rock cliffs about the river mouths of a delta to furnish this material. The significant feature of these grits, is, however, their strong content of fresh feldspars, which indicates that instead of a moist climate and abundant vegetation in the river basin that supplied this material, there prevailed desert conditions, even if we assume that there already existed sufficient vegetation on land in Ordovician time to eventually supply the carbonaceous matter for the black mud.

In our view, these Hudson grits, with their many often large fragments of Ordovician limestone and Cambrian rocks are largely the product of the marine erosion along the shores of the long troughs. The black shales themselves we consider as the deposits on the dead grounds of the deeper littoral zone, carried there by the undertow, in less severe storms. In other words, Lapworth's view (1897), that the graptolite shales are deposited parallel to the coast, in a zone of deeper quiet water, and that the black mud derives its color and fossils from the rain of graptolites and vegetable matter settling there at times of storms, appears still today with some modification best adapted to explain all peculiarities of these graptolite shales.

We see an especially strong argument for the supposition that storms often wrecked the floating swarms of graptolites with their carriers, the seaweeds, in these seas, in the fact that one finds many bedding planes, especially in the Normanskill shale, covered with the tangled and broken masses of a single graptolite species only, in some cases Dicellograptus gurleyi, in others one of the species of Diplograptus, or Nemagraptus gracilis, or one of the species of Dicranograptus. In every such case it is to be assumed that a large swarm of the species in question floating by itself had been overwhelmed by the storm, the rhabdosomes broken and foundered. On other slabs one finds the species mixed and the specimens more scattered. This condition seems to represent the normal graptolitic detritus settling on the bottom in less turbulent times.

An alternative view, suggested by Ulrich, is that cold climate destroyed them at times. This view is in agreement with the other conception that certain conglomerates associated with the graptolite shales, as the Rysedorph Hill conglomerate are of glacial origin, and it would seem to receive strong support by the discovery of glacial boulder clay of Ordovician age in Alaska by Kirk (Kirk 1919). On the other hand, the principal graptolite shales, here mentioned, are of Chazy, Black River and Trenton age, in which the development of corals, bryozoans, coralline algae or other organisms, that flourish best in warm water, and the variety of organic life in general, have always been held to proclaim congenial climatic conditions for these periods; and furthermore these limestones with their abundance of organic forms occur often in close horizontal proximity of the graptolite shales, as in the Mohawk valley. The climate was then, in Middle Ordovician time at least, a warm and favorable one in the sea extending across New York. If, then, the masses of foundered graptolites found from time to time upon the surfaces of the shale, are to be attributed to the climate, it must be assumed that cold currents coming from less favored regions were sometimes able to enter into the epicontinental seas and to cripple or even extinguish life.

While the Schaghticoke, Deep Kill and Normanskill rocks are deposited in narrow, long troughs, the Canajoharie, Utica and Deer River black shales have spread over broader areas; and as we noted before, while the sandstones and shales of the former formations are practically barren of fossils, save the graptolites and a few other pelagic forms, the latter contain fairly large mixed benthonic faunas.

Another important difference is that the black shales of the second group are more or less calcareous, while those of the first lack the calcareous admixture. Ulrich (1911, p. 358) has pointed out the difference "in general aspect and composition of black noncalcareous shale faunas from that of limestones and calcareous shales, whether blue, green or black that are found in the same areas." While the non-calcareous black shales contain mostly but small, ubiquitous brachiopods with phosphatic, inarticulate shells, and among mollusks small depauperate pelecypods that are byssiferous forms and were obviously pseudoplanktonic or attached to floating objects, the calcareous black shales contain faunas that indicate more favorable bottom conditions. A glance at the list of Utica fossils given on p. 36 will show that these black shales contain, besides the abundant graptolites, a fauna of considerable size and variety of composition. The same is true of the Canajoharie shale (see Ruedemann, 1912, p. 23) which has furnished in one horizon twenty-three different types of brachiopods, gastropods, pelecypods, cephalopods, trilobites and ostracods.

Nevertheless, the fauna of the black calcareous shales is distinctly depauperated when compared with that of the limestones, which the shale replaces either horizontally or vertically, not only in the variety of forms, but also in the number of individuals and their comparative size. Certain classes, as the bryozoans and corals that abhor muddy water, are absent altogether. The faunas of these black shales, moreover, are always similar in composition. In the case of the Canajoharie, Utica and Deer River shales, there always appear notwithstanding the differences in age between them, and besides the diagnostic graptolites, the same lingulas, Leptobolus insignis, small ctenodontas and pterineas, small liospiras similar cephalopods (Geisonoceras), Triarthrus becki and eatoni, and small primitive ostracods of the Primitia group. It is for this reason that these shales were naturally grouped together as Utica shale, until the graptolites suggested their different age and marine connections.

While thus the conditions in the areas where the black calcareous shales were deposited, were not so utterly uncongenial to bottom life, they were nevertheless, still unfavorable. This condition is principally due to the influx of the black mud, for in the transitional beds (Dolgeville beds) richly fossiliferous limestone beds alternate with fairly barren black shale bands. In deeper basins, such as the Utica basin, even a condition of more severe stagnancy may have developed at times, as suggested by the complete barrenness of some beds and the presence of iron pyrite.

The seas in which the Canajoharie and Utica shales were deposited, had their shore-lines in the east and northeast and were more or less open to the west, for these black shales are replaced in the east by sandstones and shales (Schenectady beds) and seaward or toward the west and northwest by limestone (Trenton and Cobourg limestone). The more shoreward situated Schenectady beds exhibit many signs of shallow water origin and may well, in part at least, be delta deposits. Their fauna is, however, pronouncedly marine, and their north-south extension and great thickness (over 2000 feet, see Ruedemann, 1912) suggest that like the overlying Indian Ladder beds, they were largely deposited in a sinking trough. The great thickness of the Utica shale about Utica would also suggest a local basin or depression southwest of Adirondackia, as noted before.

With all these local basins and barriers, however, there is sufficient continuity of rocks and faunas to forbid the assumption of complete separation; and the spreading of the black shale far to the west in later Utica time is clear proof of the very wide westward extension of the Utica sea. This fact, together with the calcareous nature of the black Utica and Canajoharie shales and their horizontal changes into limestone on one side and sandstone and shale in the other, would exclude the possibility of their being delta deposits, formed in the small embayments between the mouths of a river.

It is rather to be inferred that these black shales, the organic matter of which was derived to a great part from the rich seaweed flora[1] of the eastern and northern coasts (see seaweeds, described by Ruedemann 1912, and this publication) were carried into the deeper parts of the littoral district[2] by the powerful undertow, under the influence of strong west winds. This would very well agree with the observation by the writer (Ruedemann, 1897) of a prevailing westward direction of the fossils that are found in parallel arrangement in the black Canajoharie and Utica shales (mainly graptolites and small cephalopod shells).

The wide distribution of the Utica black shale westward calls for a further agency of wider geographic influence than the undertow and this is found in the presence of marine currents in the epicontinental Utica sea. The narrow zone of distribution of the Canajoharie black shale, however, is fully accounted for by the undertow action of a stormbeaten coast.

LORRAINE GROUP

SECTIONS OF LORRAINE BEDS

The first section of the Lorraine with fossil lists was published by Walcott (1890, p. 347). It was made along the south branch of Sandy creek, Jefferson county, the middle course of which is known as the "Lorraine gulf." Walcott distinguished three divisions in the shales, namely, the black shale at the base, which he referred to the Utica, the shale and alternating sandstone, and the sandstone and alternating shale. He thus recognized the lithologic and faunal distinction between the lower and upper Lorraine beds, which, in a general way, correspond to that between the Eden and Maysville beds in the west. By combining the Lorraine Gulf, Pulaski and Salmon River Falls sections, he computed a thickness of 810 feet for the entire Lorraine group.

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[1] It has been lately pointed out by Walther (Walther, 1910, p. 108) that the early Paleozoic and Prepaleozoic seas must have been alive with a luxuriant flora of soft, gelatinous algae that left no trace of their structure except their carbonaceous substance on account of their softness of tissue. They were obviously the source of maintenance of the rich early Paleozoic faunas, even trilobites included, that show no traces of masticating and triturating organs and were also still very little rapacious. In time the algae were forced to develop harder tegumental layers or even calcareous deposits to protect themselves from the attacks of their ever increasing enemies. It is then that we begin to find besides the numerous calcareous algae, the impressions of algae, as in the Schenectady beds (see Ruedemann, 1912). The great variety of forms of algal remains discovered by Walcott (1919, p. 225) in the Middle Cambrian of British Columbia, that were of irregular globose or spheroidal shape (see Morania) and possessed a mucous or gelatinous tegument as the recent Nostocaceae to which the Moranias are referred, has thrown an interesting light upon this hitherto unknown wealth of plant life in the primordial seas. The Utica shale, as well as the other graptolite shales of New York, contains great quantities of irregular or often roundish carbonaceous patches lacking all structure except the parallel shrinkage cracks in the often thick bodies, which have misled Whitfield to describe the forms as sponges (Rhombodictyon) occurring in the Normanskill shale).

[2] This term is used as defined by Grabau in Principles of Stratigraphy, p. 697, as that part of the sea above the deep sea portion.

His section, with its interesting fossil lists, is here copied:

Section along the south branch of Sandy creek, Jefferson county, N. Y.

1 Trenton limestone as exposed in the town of Ellisburgh...... 25 feet.

2 Dark bituminous shale in bands, alternating with a smoother lead-colored shale. Thin layers of a gray, fine-grained, calcareous sandstone occur at various horizons in the shale. This shale is characterized by the fauna of the Utica shale................180 feet.

Fossils: Endoceras proteiforme, Triarthrus beckii, and Trinucleus concentricus. At 150 feet up in the shales a few minutes' work of collecting gave: Leptaena sericea, Orthis testudinaria, Cleidophorus planulatus, Tellinomya, sp. undet., Triarthrus beckii, and Trinucleus concentricus.[1]

3 Alternating bands of shale and gray, fine-grained, calcareous sandstone; the shale predominating..........100 feet.

Fossils: Diplograptus pristis, Hippothoa inflata, Paleschara (sp. undet.), Monticulipora (2 sp. undet.), Pholidops cincinnatiensis, Trematis terminalis, Leptaena sericea, Strophomena alternata, Orthis testudinaria, Zygospira modesta, Avicula insueta, Modiolopsis anadontoides, Cleidophorus planulatus, Nucula levata, Bellerophon cancellatus, Pleurotomaria (small sp. undet.), Endoceras proteiforme, Triarthrus beckii, Calymmene callicephala. At the summit of this belt I found: Pholidops subtruncata, Leptaena sericea, Orthis testudinaria, Cleidophorus planulatus, Ambonychia radiata, and Triarthrus beckii.[2]

4 Gray, fine-grained, calcareous sandstone, with parting of black and drab shale,[3] yielding on Sandy creek the following fauna: Leptaena sericea, Strophomena alternata, Ambonychia radiata, Modiolopsis modiolaris, Cleidophorus planulatus, and Calymene callicephala. On the Salmon river, at Pulaski, Oswego county, the

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[1] On the line of the section, the first forty feet of the shale is concealed by drift deposits, but on the north branch of Sandy creek it may be seen in numerous exposures.

[2] This is the highest zone at which Triarthrus beckii was found.

[3] On the line of Sandy creek section there is about 75 feet of this series of rock exposed.

base of the series is seen and about 50 feet of strata. Fossils are abundant, but as they are better preserved in the drift to the south in Lewis and Oneida counties, the following typical species only were collected: Monticulipora discoidea, M. gracilis, Cruziana *sp.*, Glyptocrinus decadactylus, Leptaena sericea, Strophomena alternata, Ambonychia radiata, Modiolopsis modiolaris, Nucula levata, Cleidophorus planulatus, Cyrtolites ornatus, Cornulites curvatus, and Calymene callicephala. At Salmon river falls the summit of this series is seen just above the falls, and 130 feet of strata are shown at the falls and below. The strike of the beds at Pulaski and at the falls is nearly the same, and the difference of altitude between them is 320 feet. Adding the thickness of the exposure at Pulaski to the supposed concealed thickness (320 feet) and the thickness at the falls (130 feet), we have ....500 feet.

Fossils: This belt is characterized by the upper Lorraine fauna as represented by the following species: Orthis testudinaria, Modiolopsis modiolaris, Murchisonia milleri, Cyrtolites ornatus, etc. From the drift blocks of the division there have been collected: Monticulipora discoidea, M. lens, M. mamillata, M. (2 sp. undet.), Glyptocrinus decadactylus, Leptaena sericea, Lingula quadrata, Orthis erratica, O. biforata, O. occidentalis, O. testudinaria, Pholidops subtruncata, Strophomena alternata, S. alternata var. nasuta, S. tenuistriata, Ptilodictya (sp. undet.), Bellerophon bilobatus, Cyrtolites ornatus, Murchisonia bellicincta, M. gracilis, M. milleri, Pleurotomaria subconica, P. tropidophora, Raphistoma lenticulare, Endoceras (sp. undet.), Orthoceras (4 sp. undet.), Ambonychia radiata, Avicula demissa, Cleidophorus planulatus, Lyrodesma poststriatum, L. pulchellum, Modiolopsis curta, M. faba, M. nasuta, M. modiolaris, M. pholadiformis, M. truncata, Orthodesma contractum, O. parallelum, Conchicolites flexuosus, Acidaspis (sp. undet.), Asaphus platycephalus, Calymmene callicephala, and Trinucleus concentricus.

Gray sandstone ....30 feet

810 feet

Ulrich (1913, p. 623, 627), in his paper on the Ordovician-Silurian boundary, read before the International Congress, has fully discussed the correlation of the New York Lorraine and the overlying Oswego sandstone with the formations of the Ohio and Allegheny basins from observations made in a joint trip with Doctor Foerste. He concludes that the Fairview division of the Maysville is possibly represented in New York by the Pulaski shale, and that the Oswego sandstone, hitherto considered as the base of the Silurian, is to be correlated, chiefly on account of its stratigraphic position, with the McMillan, or the second division of the Maysville, and the last of the Ordovician in America. He records the finding in the lower part of the Oswego sandstone at Lorraine and along Salmon river, of an association of pelecypods, like Whiteavesia corrugata, Orthodesma nasutum and Ischyrodonta unionoides, that is found at Cincinnati only in the basal part (Bellevue member) of the McMillan formation.

The following faunules are recorded from the beds exposed along Salmon river at Bennett's Bridge, which are in the zone of prevailing sandstones, and hence properly considered as belonging to the Oswego sandstone:

1 At the bottom of the river just below the new power dam at Bennett's Bridge:

"Byssonychia radiata, Whiteavesia corrugata, Orthodesma nasutum, Ischyrodonta unionoides (? I. curta Conrad *sp.*), Lyrodesma *cf.* poststriatum, Archinacella *sp.*, Cyrtolites ornatus, and Rafinesquina *aff.* alternata."

2 Midway between the power dam and the falls, some 20 to 30 feet higher in the section:

The same species as above, and also: "Columnals of undetermined crinoid, Rafinesquina squamula mucronata, Pholidops *cf.* cincinnatiensis, Catazyga erratica, Cleidophorus planulatus, Modiolopsis modiolaris, Whiteavesia *aff.* cincinnatiensis, and Orthoceras sp. undet."

3 The highest fossiliferous layers observed in the cliff at Salmon river falls contain, in poor preservation:

"Rounded crinoid columnals, Inocaulis (?) *sp.*, several trepostomatous Bryozoa, Byssonychia radiata, Modiolopsis *sp.* (related to M. milleri and M. concentrica), numerous small Pelecypoda suggesting Modiolopsis faba and species of Psiloconcha, Ctenodonta and Cleidophorus, Orthoceras *sp.* (has strong transverse striations), Endoceras *sp.* and fragments of Isotelus."

The paleogeography of this Oswego formation is fully discussed and we shall have occasion to return to this part of the paper in a later chapter.

A further general section of the Lorraine of New York has been furnished by Foerste (1916, p. 6) whom we quote:

> At the village of Lorraine, in Jefferson county, New York, the following fossils occur in the creek in the northeastern corner of the village:
>
> Heterocrinus columnals
> Glyptocrinus columnals
> Cornulites of straight, free type
> Pholidops subtruncata
> Dalmanella of testudinaria group
> Glyptorthis crispata
> Rafinesquina alternata (flat form)
> Plectambonites sericeus
> Catazyga erratica
> Byssonychia radiata
> Clidophorus planulatus
> Colpomya faba-pusilla
> Cuneamya scapha-brevior
> Ctenodonta lorrainensis
> Modiolopsis of concentrica group
> Lyrodesma poststriatum
> Archinacella pulaskiensis
> Cyrtolites
> Hormotoma gracilis-sublaxa
> Trinucleus concentricus
> Calymmene *sp.*
>
> At a moderately higher horizon, 2 miles eastward, on the road to Worthville, the same species as in the preceding list are found, with the addition of:
>
> Ischyrodonta curta
> Sinuites cancellata
>
> At a slightly higher horizon, at Worthville, the following are added to the list, still associated with Trinucleus concentricus:
>
> Rafinesquina nasuta
> Modiolopsis modiolaris
> Orthodesma nasutum
>
> At still higher horizons, east of Worthville, Ischyrodonta curta, associated with Modiolopsis modiolaris, and Orthodesma nasutum, becomes more common, and Rafinesquina mucronata is added to the list.

Also Foerste completed his section of the Lorraine formation by adding the faunules at the Bennett Bridge and the Salmon river falls.

He writes (*op. cit.* p. 7):

> Still higher horizons are exposed at the Bennett bridge, about a mile down stream from the Salmon river falls. Here the following species occur:
>
> Rafinesquina alternata
> Rafinesquina mucronata
> (No Plectambonites or Dalmanella was noted).
> Byssonychia radiata
> Pholadomorpha pholadiformis
> Orthodesma nasutum
> Lyrodesma poststriatum
> Archinacella pulaskiensis

Salmon river falls:

Glyptocrinus columnals
Pholidops subtruncata
(Dalmanella and Plectambonites absent)
Rafinesquina mucronata
Rafinesquina alternata
Catazyga erratica
Byssonychia radiata
Modiolopsis modiolaris
Pholadomorpha pholadiformis
Ischyrodonta curta
Clidophorus planulatus
Lyrodesma poststriatum
Cyrtolites ornatus
Isotelus *sp.*
(No Trinucleus) [1]

The outcrops of the Lorraine beds in New York, like those of the underlying Atwater Brook and Deer River formations, occur

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[1] In letters received after subsequent visits Doctor Foerste has added to the fauna of the Bennett's bridge:

Arthraria
Catazyga erratica
Cuneamya scapha brevior
Clidophorus planulatus
Ischyrodonta curta
Pterinea demissa
Clathrospira subconica
Cyrtolites ornatus
Orthoceras *sp.*
Endoceras *sp.*

An upper Lorraine or Pulaski fauna was also found by the same author in the locality mentioned by Vanuxem, south of Dix, south of Rome; (letter of Sept. 1916) namely:

Rafinesquina mucronata
Dalmanella
Modiolopsis modiolaris
Ischyrodonta curta
Cymatonota pholadis
Clidophorus planulatus
Sinuites cancellatus
Cyrtolites ornatus
Lophospira bowdeni

all along the margins of the Tug Hill plateau. The name " Tug Hill plateau" has been proposed for this distinct physiographic province of northwestern New York by W. J. Miller (1914, p. 21). It is "a highland mass of considerable extent entirely separated from the neighboring provinces," reaching an altitude of 2100 feet and "rapidly sloping downwards to the lowlands of the Mohawk valley and Ontario plain provinces on the north and west, while on the east and north the Black river valley sharply separates this province from the Adirondack and the St Lawrence valley provinces." This great plateau which is merely an erosion remnant of the great upraised Cretaceous peneplain, is composed entirely of Ordovician rocks, and the still unsettled, rugged top is formed of the Oswego sandstone. The steep descent over a series of high, steep terrace fronts, that are intersected by deep ravines, furnishes excellent long continuous outcrops, which fail only in the upper Lorraine where the top of the plateau is reached. The sections of Wood creek and around Quaker hill are on the south side of this plateau, those of Moose creek, Mill creek, Atwater brook, Whetstone gulf on the east side, that of Deer river on the north side and the Lorraine gulf and Bennett's Bridge sections on the west side.

Owing to the southwest dip of the strata, one finds exposed on the northeast side of the plateau, in the terraces, the whole series of rocks, from the Potsdam sandstone upward, while on the southwest side, the capping Oswego sandstone has dipped to the foot of the plateau terraces.

Section along Wood creek, between Lee's Center and Stokes, 7 miles northwest of the city of Rome, Oneida county, N. Y. This section, the only fairly complete one of Lorraine beds that the writer could find in the neighborhood of Rome or in the southern part of the Tug Hill plateau region, begins near the base of the Lorraine and leads through 340 feet of rock in a practically unbroken succession of beds.

Station 1 (Locality number 4092). Base of section; 640 feet. Exposed in the creek, less than a quarter of a mile north of the road leading from Stokes to Lee's Center.

While the directly underlying beds are covered in the neighborhood by drift, it is evident from comparison with the section on Quaker hill and the dip of the Frankfort shales, about Stokes and the Delta dam, that the beds exposed at this station are close to the base of the Lorraine, probably not more than 20 feet above it.

The beds are all black to bluish-gray, argillaceous shales, in part quite full of fossils. It is this fossiliferous shale of Frankfort appearance which is cited by Vanuxem (*op. cit.* p. 64) as being intermediate between the "Frankfort slate" and the "rocks of Pulaski village."

The following fossils were here collected:

*Mastigograptus *cf.* gracillimus (Lesquereux) rr
*Diplograptus nexus *nov.* rr
*Climacograptus *cf.* pygmaeus *nov.* r
*Heterocrinus difficilis Ulrich MS cc
*Corynotrypa delicatula (James) c
*Corynotrypa inflata (Hall) c
*Stomatopora arachnoidea (Hall) c
*Paleschara beani (James) c
*Arthropora cleavelandi (James) c
*Hallopora onealli (James)
*Hallopora onealli sigillarioides (Nicholson) cc
*Zygospira modesta (Say) cc
*Clidophorus scitulus (Emmons) c
*Byssonychia vera Ulrich rr
*Pterinea obtusiformis Ulrich MS
Pterinea *sp.* r
*Rhytimya *cf.* radiata Ulrich (young) rr
*Ctenodonta filistriata Ulrich r
Whiteavesia *sp.* rr
*Sinuites planodorsatus (Ulrich) c
*Liospira micula (Hall) c
*Eccyliomphalus *sp.* rr
*Plethospira quadricarinata *nov.* c
Clathrospira subconica (Hall) c
Liospira vitruvia (Billings) r
Lophospira bicincta (Billings) r
Eotomaria *sp. cf.* canaliculata Ulrich r
Orthoceras *cf.* transversum Miller r
cf. Paractinoceras lamellosum (Hall) r
*Cornulites progressus *nov.* rr
*Isotelus stegops Green (Ulrich) c
*Cryptolithus bellulus (Ulrich) cc
*Triathrus eatoni (Hall) r
*Calymmene senaria granulosa Foerste rr
*Bollia pulchra *nov.* rr
*Lepidocoleus jamesi (Hall and Whitfield) c

Station 2 (Locality number 4093). 665 feet. Greenish and bluish-gray argillaceous shales with some thin sandy streaks:

Crinoid columnals cc
*Dalmanella multisecta (James) r
Zygospira modesta (Say) cc
*Trematis millepunctata Hall (small) r
*Archinacella subcarinata *nov.* r.
Liospira micula (Hall) r
*Pterinea (Caritodens) demissa (Conrad) (small) r

NOTE. An asterisk in front of the species name denotes first appearance in section, a cross the last appearance.

Ctenodonta filistriata Ulrich c
Clidophorus scitulus (Emmons) c
Cryptolithus bellulus Ulrich cc
Triarthrus eatoni (Hall) c
*Odontopleura crosota (Locke) r
Calymmene senaria granulosa Foerste r
Lepidocoleus jamesi (Hall and Whitfield) r
Bollia pulchra *nov.* r

Station 3 (Locality number 4094). 670 feet. Gray argillaceous and sandy shales, also a one-foot sandstone bed:

Crinoid columnals cc
Corynotrypa delicatula (James) r
Arthropora cleavelandi (James) c
Zygospira modesta (Say) *var.* cc
*Rafinesquina *sp.* (fragment) r
Clidophorus scitulus (Emmons) c
Byssonychia vera Ulrich c
Byssonychia vera Ulrich *var.* pluricosta *nov.* r
Ctenodonta filistriata Ulrich
Rhytimya radiata Ulrich r
Geisonoceras *sp.* r
Cryptolithus bellulus Ulrich cc
Isotelus stegops (Green) Ulrich r
Calymmene senaria granulosa Foerste r
Odontopleura crosota (Locke) r
Lepidocoleus jamesi (Hall and Whitfield) c
*Primitia *cf.* cincinnatiensis Miller c
Problematicum rr

Station 4 (Locality number 4095). 680 feet. Dark gray to black shales with few very thin sandstone seams:

Crinoid columnals
Arthropora cleavelandi (James)
*Bythopora parvula James cc
Bythopora arctipora (Nich.) r
Zygospira modesta (Say) cc
Clidophorus scitulus (Emmons)
Ctenodonta filistriata Ulrich c
Byssonychia vera Ulrich r
*Colpomya intermedia *nov.* rr
*Lyrodesma conradi Ulrich rr
Liospira micula Hall rr
Cryptolithus bellulus (Ulrich) cc
Isotelus *cf.* stegops (Green) r
Odontopleura crosota (Locke) r
Calymmene senaria granulosa Foerste c
Lepidocoleus jamesi (Hall and Whitfield)

Station 5 (Locality number 4096). 695 feet. Dark shales with few thin beds of sandstone and a fossiliferous, more calcareous band. The latter consists of Hallopora onealli (James) cc and contains a few specimens of Byssonychia vera pluricosta, Cryptolithus bellulus and crinoid stems, *Station 6* (Locality number 4097). 710 feet. Here appears in the grayish shales the first band of calcareous sandstone, suggesting in its rusty-brown weathering the well-known rocks of the upper Lorraine at Pulaski and Lorraine. This layer contains:

Crinoid columnals cc
Hallopora onealli sigillarioides (Nicholson) cc
*Rafinesquina alternata centrilineata *nov.* cc
Zygospira modesta (Say) r
Byssonychia radiata Hall c
*Archinacella subcarinata *nov.* r
Sinuites cancellatus (Hall) c
*Cyrtolites ornatus Conrad c
Liospira micula Hall c
*Lophospira abbreviata (Hall) r
Lophospira *cf.* bicincta (Hall) r
cf. Paractinoceras lamellosum (Hall) c
Calymmene senaria granulosa Foerste r

Station 7 (Locality number 4098). 720 feet. Greenish gray argillaceous shales with few thin intercalations of gray sandy layers. The latter contain:

Rafinesquina alternata centrilineata *nov.* c
Ctenodonta filistriata Ulrich r
Byssonychia *cf.* radiata (Hall) c
Cryptolithus lorrainensis *nov.* c

Station 8 (Locality number 4099). 760 feet, below the first crossroad. Here brownish weathering, thin sandstone seams become more frequent. These are very fossiliferous and contain:

Mastigograptus *cf.* gracillimus (Lesquereux) r (in shale)
Crinoid columnals c
Hallopora onealli sigillarioides (Nicholson) c
Zygospira modesta (Say) cc
Rafinesquina alternata centrilineata *nov.* c
Clidophorus scitulus (Emmons) r
Colpomya intermedia *nov.* cc
Byssonychia vera Ulrich c
Lyrodesma conradi Ulrich r
*Cymatonota parallela (Hall) *var.* r
Plethospira quadricarinata *nov.* r
Liospira micula (Hall) c
Sinuites cancellatus (Hall) c
S. granistriatus (Ulrich)
Orthoceras *sp.* r
Cryptolithus lorrainensis *nov.* cc
Isotelus stegops Green c
†Triarthrus eatoni (Hall)
Calymmene senaria granulosa Foerste c
Primitia *sp. cf.* cincinnatiensis (Miller) rr

Station 9 (Locality number 5000). 790 feet, just above first crossroad. Bluish-gray mud-shales with a few thin sandy layers with iron-stained fossils, and also some thin limestone bands composed of crinoid columns; also a one-foot sandstone bed over shaly layers composed of badly squashed gastropods.

Crinoid columnals cc
Ectenocrinus simplex (Hall) rr
Arthropora cleavelandi (James) c
Stomatopora arachnoidea (Hall) rr
Hallopora onealli sigillarioides (Nicholson) r
Bythopora arctipora (Nicholson) r
*Rafinesquina ulrichi Hall & Clarke cc
*Pholidops cincinnatiensis Hall r
*Plectambonites *cf.* plicatellus Ulrich rr
*Pterinea *sp. nov.* 1 r
Lyrodesma conradi Ulrich rr
Byssonychia vera Ulrich r
*Whiteavesia subplana *nov.* cc
*Whiteavesia foerstei *nov.* rr
Clidophorus scitulus (Emmons) cc
Cymatonota parallela (Hall) var. r
Colpomya intermedia *nov.* c
Archinacella subcarinata *nov.* r
Eccyliomphalus *sp.* rr
Clathrospira subconica (Hall) c
Plethospira quadricarinata *nov.* cc
Sinuites planodorsatus Ulrich cc
Liospira micula (Hall) r
L. vitruvia (Billings) r
Cryptolithus lorrainensis *nov.* cc
Isotelus stegops Green rr
Calymmene senaria granulosa Foerste r
Odontopleura crosota (Locke) rr
*Aparchites minutissimus (Hall) c
*Bythocypris cylindrica (Hall) c
*Eopollicipes *sp.* rr
Lepidocoleus jamesi (Hall and Whitfield) r

Station 10 (Locality number 5001). 840 feet. Bluish-gray, thick bedded mud-shales, with few thin sandstone layers:

Crinoid columnals cc
Arthropora cleavelandi James c
*Rafinesquina *cf.* ulrichi (James)
*Plectambonites sericeus (Sow.) *var.* cc
Zygospira modesta (Say) cc
Clidophorus planulatus (Conrad) r (large, very flat)
Colpomya intermedia *nov.* c
Ctenodonta *nov.* (levata group) r
Archinacella subcarinata *nov.* r
Liospira micula (Hall) r
L. vitruvia (Billings) r
Plethospira quadricarinata *nov.* r
Orthoceras *sp.* r
Cryptolithus lorrainensis *nov.* cc
Isotelus spurlocki (Meek) r
Aparchites minutissimus (Hall) cc
Bythocypris cylindrica (Hall) cc

Between stations 10 and 12 fossiliferous outcrops fail. In loose shales were found, among other fossils, Zygospira concentrica Ulrich cc, and in sandstone Rafinesquina nasuta (Conrad), very typical, showing the occurrence of these fossils in this interval.

Station 12 (Locality number 5003). 925 feet. Shales with intercalations of thin sandstone beds, the latter with great numbers of Byssonychia.

Crinoid columnals cc
Bythopora gracilis (Nicholson) cc (small form of Fairmount member, *fide* Ulrich)
Dalmanella multisecta (Meek) c
Plectambonites sericeus (Sow.) c
Colpomya intermedia *nov.* c
*Byssonychia radiata (Hall) large, coarse-ribbed cc
Calymmene meeki Foerste r

Station 13 (Locality number 5004). 975 feet. Shales with gray sandstone beds of Lorraine aspect, one of which is 3 feet thick.

Crinoid columnals cc
Amplexopora (?) discoidea (Nicholson) c
*Arthropora shafferi (Meek) cc
Plectambonites sericeus (Sow.) cc
Clidophorus planulatus (Conrad) cc (large, flat)
Cymatonota parallela (Hall) c
Byssonychia radiata (Hall) c (large, coarse-ribbed)
*Whitella goniumbonata Foerste rr
Cyrtolites ornatus Conrad r
Cryptolithus lorrainensis *nov.* c
Isotelus *sp.* r
Calymmene meeki Foerste r
Aparchites minutissimus (Hall) r

Station 14. 985 feet. Shale with many gray, one-foot sandstone bands. No collection. Observed:

Byssonychia radiata Hall cc (large, coarse-ribbed)
(?) Modiodesma modiolare (Conrad) c
Cyrtolites ornatus Conrad
Liospira *sp.* (large)
Calymmene meeki Foerste c

Station 15 (Locality number 5005). 1000 feet. Shale with many gray sandstone beds, 2 feet thick and more; just below second viaduct.

*Diplograptus recurrens *nov.* cc

Sections of Northwestern. While the preceding section is on the south side of Quaker hill and of the Tuck Hill plateau in general, the sections about Northwestern are on the east side of Quaker hill and on the southeast corner of the Tuck Hill plateau.

We have before (see antea p. 56) described from Quaker hill brook, opposite Westernville, a section that leads from the Utica shale through the Frankfort beds. The Frankfort beds consist of 250 feet of very fissile, bluish-gray and black shales with intercalations of thin sandstone beds. The beds are extremely barren and the fauna very meager.

This formation is quite abruptly followed by lighter bluish-gray, more compact shales with less sandstone beds and a different faunule. The latter consists of:

Mastigograptus *cf.* gracillimus Lesquereux rr
Lingula *sp.* (fragment)
Clidophorus planulatus (Conrad) r
Ctenodonta *sp.* (minute form)
Orthoceras (fragment)
Triarthrus eatoni (*Hall*) r
Cryptolithus bellulus Ulrich r
Bythocypris cylindrica (Hall) r

We consider these as the basal beds of the Lorraine formation on account of the abrupt change from the preceding Frankfort faunule and especially the introduction of Clidophorus and Cryptolithus bellulus. These basal beds are also very barren of fossils and the faunule here given can be traced through 70 feet of rock to the top of the upper falls, where the sandstone intercalations increase and the fossils seem more frequent.

In addition to the fauna listed above there occur here:

Liospira micula (Hall) c
Isotelus stegops (Green) c

Only about 30 feet of these latter beds are exposed when the brook fails to erode through the drift.

In this important section there are thus shown both the contacts of the Utica and Frankfort, and of the Frankfort and Lorraine formations.

No other outcrop was found along this creek, but an outcrop of sandy, fossiliferous Lorraine shale occurs a mile northeast of the last outcrop or about 330 feet higher, at the road bifurcation between Hillside and Beartown, at 1276 feet A. T. Here were collected:

Pholidops subtruncata Hall c
Plectambonites sericeus (Sow.) cc
Zygospira modesta Say r
Clidophorus planulatus Conrad c
Byssonychia radiata (Hall) c
Colpomya pusilla Foerste r

This faunule indicates one of the higher horizons of the Lorraine beds.

Moose creek near Boonville. The Utica section along Moose creek is described on page 44. The Frankfort beds are poorly exposed in the flat stretch of the valley about the hamlet of Pasadena, but the Lorraine beds are well shown along the brooks coming from the plateau to the north of Pasadena. A very good section is exposed along a small northern tributary of Moose creek about one-quarter mile west of Pasadena, the rocks beginning at 1340 feet directly above the Frankfort and running through a thickness of 270 feet.

Station 8 (Locality number 5008). 1340 feet. Greenish-gray soft, thick-bedded, argillaceous rather barren mud-shale. This outcrop is on the first northern tributary west of Pasadena.

*Diplograptus nexus *nov.* rr
*Climacograptus pygmaeus *nov.* r
*Glossograptus quadrimucronatus Hall rr
*Rafinesquina ulrichi (James) rr
*Zygospira modesta (Say) rr
*Clidophorus scitulus (Emmons) r
*Liospira micula (Hall) r
*Paractinoceras *cf.* lamellosum (Hall) r
*Cryptolithus lorrainensis *nov.* r

Station 9 (Locality number 5009). 1390 feet. Dark greenish-gray and olive colored, argillaceous and slightly sandy shale, full of rusty brown fracture seams, containing an abundant and pronounced microfauna.

Climacograptus typicalis posterus *nov.* c
Diplograptus nexus *nov.* rr
Zygospira modesta (Say) c
Clidophorus scitulus (Emmons) c
Rhytimya *sp.* fragment rr
*Sinuites planodorsatus Ulrich r
Liospira micula (Hall) r
cf. Paractinoceras lamellosum (Hall)
*Isotelus stegops Green c
*Triarthrus eatoni (Hall) cc
Cryptolithus lorrainensis *nov.* c
*Aparchites minutissimus (Hall) c
*Bollia pulchra *nov.* rr
Primitia rudis Ulrich r

Station 10 (Locality number 5010). 1450 feet. Dark gray mud-shales.

Crinoid columnals rr
Diplograptus nexus *nov.* rr
Zygospira modesta (Say) rr
*Triarthrus eatoni (Hall) cc
Cryptolithus lorrainensis *nov.* rr
*Lepidocoleus jamesi (Hall and Whitfield) rr

Stations 11–12 (Locality number 5011). 1510–15 feet. Shales.

Crinoid columnals c
*Hallopora onealli sigillarioides (Nicholson) r
Rafinesquina *cf.* ulrichi (James) rr
Clidophorus scitulus (Emmons) *c*
*Pterinea *sp. nov.* 1
Ctenodonta filistriata *Ulrich*
Colpomya intermedia *nov.* rr
Rhytimya *sp.* rr
*Archinacella subcarinata *nov.* rr
Liospira micula (Hall) rr
Sinuites *sp.* r
*Trochonema (Eunema) nitidum Ulrich rr
Geisonoceras *aff.* tenuitextum Hall rr
Cryptolithus lorrainensis *nov.* c
Triarthrus eatoni (Hall)
Isotelus stegops Green r
Lepidocoleus jamesi (Hall and Whitfield) rr

Stations 13–14. 1450 feet. Prevailing shale with some sandy layers. Here occur besides crinoid columnals:

Rafinesquina nasuta (Conrad)
Cymatonota pholadis (Conrad)
Byssonychia radiata (Hall)

Station 15 (Locality number 5012). 1600 feet. Just below the bridge gray shales and calcareous, rusty, weathering sandstone beds of typical Lorraine aspect and thicker sandstone banks. The fauna contains:

Zygospira concentrica Ulrich
Dalmanella multisecta (Meek)
Plectambonites *cf.* rugosus (Meek)
Byssonychia radiata Hall
Clidophorus planulatus (Conrad)
Liospira *sp.* ind.
Cryptolithus lorrainensis *nov.*

A little above the bridge the section ends. The last bed here still contains Dalmanella multisecta and Calymmene meeki.

Mill creek near Turin. The Utica and Frankfort portions of this fine section have been described on page 45. It was seen there that the Frankfort facies is reduced to 40–50 feet and characterized by the presence of Glossograptus quadrimucronatus typus in profusion in station 7.

Station 8 (Locality number 5018). 1610 feet. Dark gray shale with bluish-black layers of shale and a one-foot sandstone bank The black shale contains:

*Climacograptus pygmaeus *nov.* c
*Clidophorus scitulus (Emmons) rr
*Triarthrus eatoni (Hall) rr

This horizon corresponds to the basal Lorraine beds observed on Quaker hill and in the Moose creek section. The beds are equally barren, but the arrival of a new fauna is indicated by the presence of Clidophorus scitulus.

Station 9 (Locality number 5019). 1620 feet. Ten feet higher up in similar dark bluish-gray argillaceous shale with sandy streaks, some bands contain a large assemblage of fossils and thin sandy shale layers are full of crinoid columnals. There occur:

*Zygospira modesta (Say) rr
Clidophorus scitulus (Emmons)
*Ctenodonta filistriata Ulrich r
*Liospora micula (Hall) c
*Paractinoceras lamellosum (Hall) rr
Triarthrus eatoni (Hall)
Dilobella lorrainensis *nov.* cc

Station 10 (Locality number 5020). 1660 feet. Prevailing shales with intercalated thin sandy beds; the latter full of crinoid columnals.

Crinoid columnals c
*Diplograptus nexus *nov.* r
*Pholidops cincinnatiensis (Hall) c
Zygospira modesta (Say) c
*Rafinesquina ulrichi (James) cc
Clidophorus scitulus (Emmons) c
Ctenodonta filistriata Ulrich r
*Pterinea *sp. nov.* 1
*Colpomya intermedia *nov.* r
*Archinacella subcarinata *nov.* rr
*Cyrtolites ornatus Conrad rr
*Geisonoceras *cf.* tenuitextum Hall rr
Cryptolithus bellulus Ulrich c
Triarthrus eatoni (Hall)
Odontopleura crosota (Locke) rr
*Lepidocoleus jamesi (Hall and Whitfield) c
*Aparchites minutissimus (Hall) c
Dilobella lorrainensis *nov.* cc
*Bythocypris cylindrica (Hall) c

Station 11 (Locality number 5021). 1690 feet. Bluish-gray shales without sandstone intercalations.

Diplograptus nexus *nov.* rr
Rafinesquina ulrichi (James) c
Zygospira modesta (Say) c
Cryptolithus bellulus (Ulrich) c
Triarthrus eatoni (Hall) (remains completely cover surface of one layer)
*Isotelus stegops Green r

Station 12 (Locality number 5022). 1710 feet. Bluish-gray shales without sandstone intercalations.

Crinoid columnals cc
Diplograptus nexus *nov.* cc
*Climacograptus pygmaeus *nov.* r
*Corynotrypa delicatula (James) rr
*Paleschara *sp.*
*Rafinesquina alternata (Emmons) c
*Zygospira concentrica Ulrich cc (completely covers one surface)
Zygospira modesta (Say) c
Clidophorus scitulus (Emmons)
Ctenodonta filistriata Ulrich c
Pterinea *spec. nov.* I. r
Colpomya intermedia *nov.*
Rhytimya alta *nov.* rr
*Byssonychia *cf.* radiata (Hall) rr
*Archinacella subcarinata nov.
*Liospira americana Billings r
Plethospira quadricarinata *nov.*
*Lophospira abbreviata (Hall) rr (cited by Hall from Turin)
Cyrtolites ornatus Conrad rr
Geisonoceras *cf.* tenuitextum (Hall) rr
Cryptolithus bellulus Ulrich r
Triarthrus eatoni (Hall)
Isotelus stegops (Green) r
Calymmene senaria granulosa Foerste rr
Aparchites minutissimus (Hall) c
Bythocypris cylindrica (Hall) c

Station 13. 1760 feet. At about 1750 feet sandstone beds become more prominent than before. The fauna consists of abundant crinoid stems, Byssonychia radiata, Cymatonota parallela, Zygospira concentrica and Hallopora onealli sigillarioides.

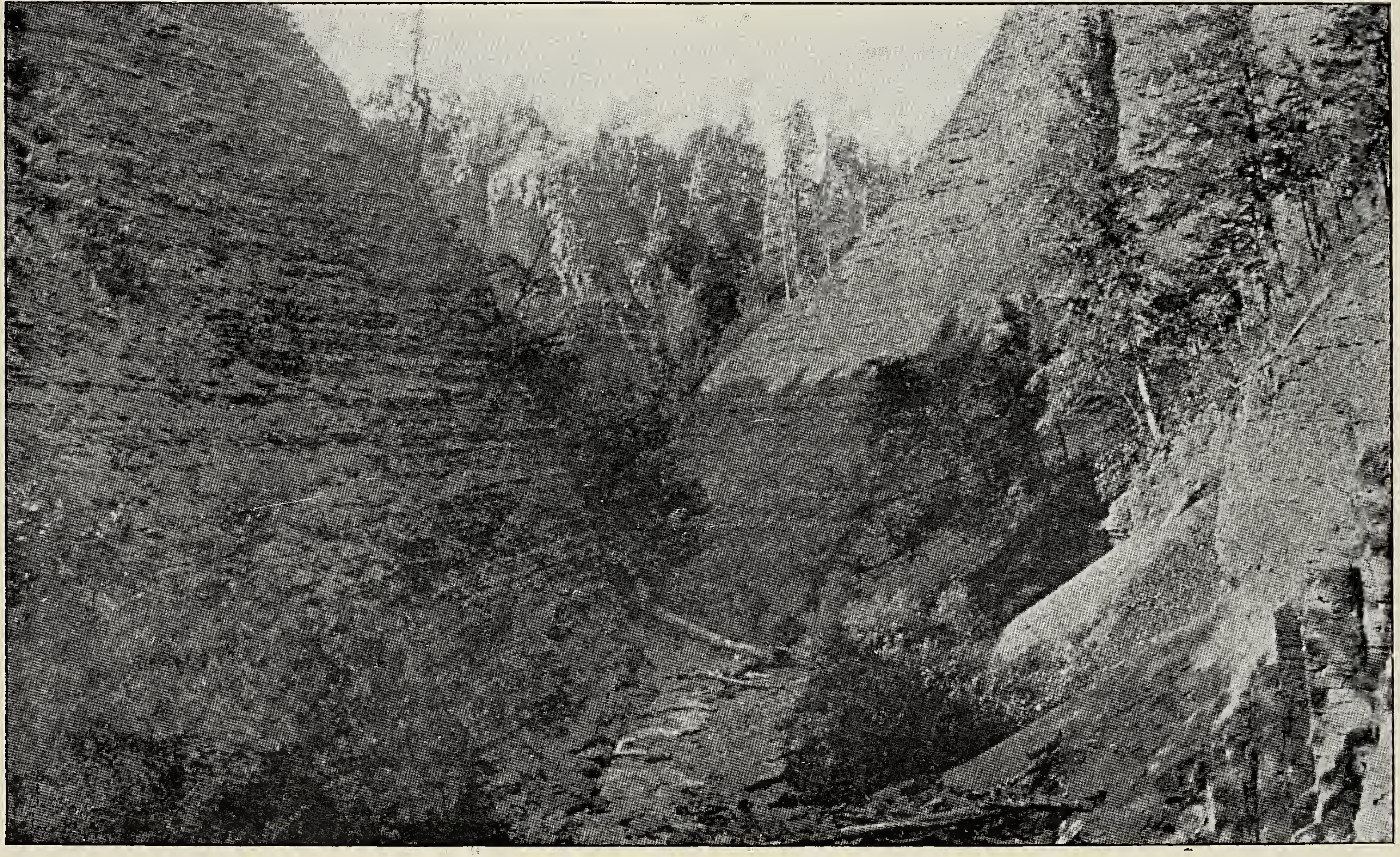
Station 14. At 1770 feet Plectambonites sericeus (Sow.) appears as a common fossil.

Station 15 (Locality number 5023). 1780 feet. Just below bridge. There occur in sandy layers:

Crinoid columnals cc
Pholidops cincinnatiensis Ulrich c
Dalmanella *cf.* multisecta (Meek) c
Plectambonites sericeus (Sow.) cc
Clidophorus scitulus (Emmons)
Ctenodonta filistriata Ulrich c
Colpomya intermedia *nov.* c
Byssonychia radiata (Hall) cc
Cyrtolites ornatus Conrad r
Rhytimya *sp.* rr
Calymmene senaria granulosa Foerste r
Odontopleura crosota (Locke) rr

Above the bridge a crinoidal limestone bed, one-half foot thick is exposed and the sandstone beds prevail above the shales. Plectambonites sericeus is the most common fossil in the shales.

Plate 2



Whetstone Gulf. Type-locality of Whetstone Gulf formation. From N. Y. State Mus. Bul. 135, pl. 9.

Fifty to seventy feet higher the last outcrops of the section are seen. There the rock is typically upper Lorraine or Pulaski in character, with gray arenaceous limestone beds weathering into a rusty brown sandstone. These beds carry large Byssonychias and the shale the typical Clidophorus planulatus.

Whetstone gulf near Martinsburgh. The Utica and Frankfort facies of this section have been recorded on page 45.

Station 5 (Locality number 5027). 1400–80 feet. Dark gray shales with very thin gray sandstone layers. Beds very barren, especially the shale as in the Frankfort beds. The sandy layers contain:

Climacograptus pygmaeus nov. c
Climacograptus typicalis posterus nov. c
*Diplograptus nexus *nov.* r
*Arthropora cleavelandi (James)
†Leptobolus insignis Hall r
Zygospira modesta (Say) cc
*Colpomya intermedia nov. c
*Ctenodonta filistriata Ulrich
*Liospira micula Hall r
*Cryptolithus bellulus (Ulrich) r
*Triarthrus eatoni (Hall) r
*Aparchites minutissimus (Hall) c

Station 6 (Locality number 5028). 1480–1530 feet. Gray shales and few thin sandstone intercalations; mostly barren.

Crinoid columnals
Climacograptus pygmaeus *nov.* r
Diplograptus nexus *nov.* c
*Plectambonites sericeus (Sow.)
Hyolithes pumilus *nov.* rr
*Clidophorus scitulus (Emmons) c
*Cuneamya *sp.* rr
Liospira micula (Hall) r
Cryptolithus bellulus (Ulrich) c
Triarthrus eatoni (Hall)
*Calymmene senaria granulosa Foerste rr
*Odontopleura crosota (Locke) rr
*Bythocypris cylindrica (Hall) c
*Bollia pulchra *nov.* r
Aparchites minutissimus (Hall) c
*Primitia rudis Ulrich r
*Primitia unicornis Ulrich *var.* r

Station 7 (Locality number 5029). 1550 feet. Gray argillaceous and sandy shale.

Crinoid columnals c
Arthropora cleavelandi (James) r
*Pholidops cincinnatiensis Hall r
*Trematis millepunctata Hall rr
Plectambonites sericeus (Sow.) cc
*Dalmanella multisecta Meek cc
Clidophorus planulatus (Conrad) c

*Rhytimya radiata Ulrich r
*Cymatonota parallela (Hall)
Cryptolithus bellulus (Ulrich) c
Triarthrus eatoni (Hall)
Calymmene senaria granulosa Foerste r
Odontopleura crosota Locke rr
*Lepidocoleus jamesi (Hall and Whitfield) r
*Primitia rudis Ulrich c
Aparchites minutissimus (Hall) c
Bythocypris cylindrica (Hall) c
Bollia pulchra *nov.* r

Station 8. 1595 feet. Here the rock is composed of as much sandstone as shale, the sandstone strata, however, being still very thin. Besides the ever present crinoid columnals there occur:

Diplograptus nexus *nov.*
*Rafinesquina alternata centrilineata *nov.*
*Byssonychia vera Ulrich
Cryptolithus bellulus Ulrich

Station 9 (Locality number 5030). 1625 feet. Thicker sandstone beds and shale regularly alternating.

*Arthrariella lorrainensis *nov.* cc (fills one bed)
Crinoid columnals
Arthropora cleavelandi (James) c
Pholidops cincinnatiensis Hall c
Rafinesquina centrilineata *nov.* c
Plectambonites sericeus (Sow.) cc
*Dalmanella *cf.* emacerata Hall c
Zygospira modesta Say cc
*Zygospira *aff.* cincinnatiensis Ulrich r
*Byssonychia vera Ulrich c
*Clidophorus scitulus (Emmons) c
*Colpomya intermedia *nov.* c
Whitella *cf.* goniumbonata Foerste
*Ctenodonta pectunculoides (Hall) c
*Pterinea *sp. nov.* 1, r
Liospira micula Hall c
*Sinuites granostriatus (Ulrich) rr
*Cryptolithus bellulus Ulrich
Triarthrus eatoni (Hall) r
*Isotelus stegops Green r
Calymmene senaria granulosa Foerste rr
Odontopleura crosota (Locke) rr
Lepidocoleus jamesi (Hall and Whitfield) c
Bythocypris cylindrica (Hall) c
Aparchites minutissimus (Hall) cc
Primitia rudis Ulrich r

Stations 10–11 (Locality numbers 5031, 5032). 1655–1740 feet. Shales alternating with beds of sandstone and impure limestone, the latter fossiliferous, the shales partially barren. These beds contain:

*Arthraria *sp. nov.* rr
Crinoid columnals cc
Diplograptus nexus *nov.* cc (in sandstone, oriented)

Dalmanella *cf.* emacerata Hall c
*Plectambonites rugosus (Meek) cc
*Byssonychia radiata (Hall) c
Byssonychia vera Ulrich c
Cymatonota parallela Hall r
*Clidophorus scitulus (Emmons)
Colpomya intermedia *nov.* c
Ctenodonta pectunculoides (Hall) c
*Hormotoma gracilis sublaxa (Ulrich) rr
Paractinoceras lamellosum (Hall) c
Calymmene *cf.* meeki Foerste rr

Station 12 (Locality number 5033). 1745 feet. A thin limestone bed at base of narrow gorge below first falls is composed of crinoid columnals, fragmental branching bryozoans and large zoariums of *Escharopora pavonia (M. E. & H.) cc, which is the most characteristic form of the bed as well as fragments of Rafinesquina, Plectambonites and Zygopsira. The alternating sandstone and shale which extend for more than 100 feet in the vertical cliff and are not sufficiently accessible for extensive collecting, contain:

Diplograptus nexus *nov.* c (in sandstone)
*Amplexopora (?) discoidea (Nicholson)
Bythopora gracilis (Nicholson) r
Cornulites progressus *nov.* rr
*Pholidops subtruncatus Hall r
Dalmanella fultonensis Foerste *mut.* rotunda *nov.* cc
Plectambonites sericeus (Sow.) c
Clidophorus planulatus Hall cc (very large)
Colpomya intermedia *nov.* r
*Cyrtolites ornatus Conrad r
*Lophospira abbreviata Hall rr
Calymmene *sp.* r
Lepidocoleus jamesi (Hall and Whitfield) c
Primitia *cf.* rudis Ulrich
Bythocypris cylindrica (Hall) r

Station 13 (Locality number 5035). 1780–1800 feet. Beds belonging in the upper horizon of station 12 were poorly exposed along the road in the gutter leading from Martinsburgh across the west end of the gulf. They contain:

*Lingula *aff.* bisulcata Ulrich rr
Plectambonites sericeus (Sow.) c
Dalmanella multisecta (Meek) *var.* cc
Colpomya intermedia *nov.* r

Station 14 (Locality number 5034). 1840–60 feet. Thick sandstone beds with intercalated shale and limestone, this series following rather abruptly the thinner alternations of sandstone and shale of the preceding station. The beginning of these heavy-bedded sandstones causes the waterfall below the road crossing at the western end of the gulf. Some of the sandstone beds are ripple-marked and cross-bedded. The sandstone beds are barren, while the calcareous sandstones are very fossiliferous. The calcareous beds contain:

Amplexopora (?). discoidea (Nicholson) r
Pholidops subtruncata Hall c
*Dalmanella multisecta (Meek) *var.* cc
Zygospira (?) erratica Hall r
Pterinea (Caritodens) demissa (Hall)
Byssonychia radiata Hall cc
Sinuites cancellatus (Hall)
*Clathrospira subconica (Hall) r
Calymmene meeki Foerste r

The shale contains:

*Stigmatella irregularis Ulrich cc
Pholidops subtruncatus Hall cc
*Dalmanella multisecta (*Meek*) *var.* c
*Whiteavesia *sp.* c
*Cuneamya ovata *nov.* c
*Whitella goniumbonata Foerste r
*Orthodesma *sp. nov.* r
*Modiodesma modiolare (Conrad) c
*Psilonychia *sp.*
*Rhytimya producta Ulrich r
Byssonychia radiata Hall c
Colpomya pusilla Foerste
*Ctenodonta perminuta Ulrich c
Clidophorus planulatus Hall cc (small form)
Cyrtolites ornatus Conrad c (large form)
Liospira micula Hall c
Sinuites cancellatus (Hall) cc
Paractinoceras lamellosum (Hall) c
Bythocypris cylindrica (Hall) c

Some 20 feet above the bridge, the creek enters the thick drift mass that covers the plateau formed by the thick-bedded sandstones of the upper Lorraine and extends to the foot of the Oswego sandstone escarpment, thus hiding the uppermost 100 feet of the Lorraine section from view.

Lorraine gulf section. The " Frankfort " portion of this section is recorded on page 47. The lowest beds (black shales) observed there contain, besides the characteristic graptolites of the Deer River formation, Clidophorus scitulus (small form), Elpe radiata, and in a thin sandstone band at the top, Diplograptus nexus. Of these Elpe radiata is a Fulton species of the Cincinnati section; the two others are advance forms of the succeeding formation. This black shale is directly followed by gray shales and sandstone, which are barren, but in a band of black shale, 10 feet above the Deer River shale, have afforded the following fossils:

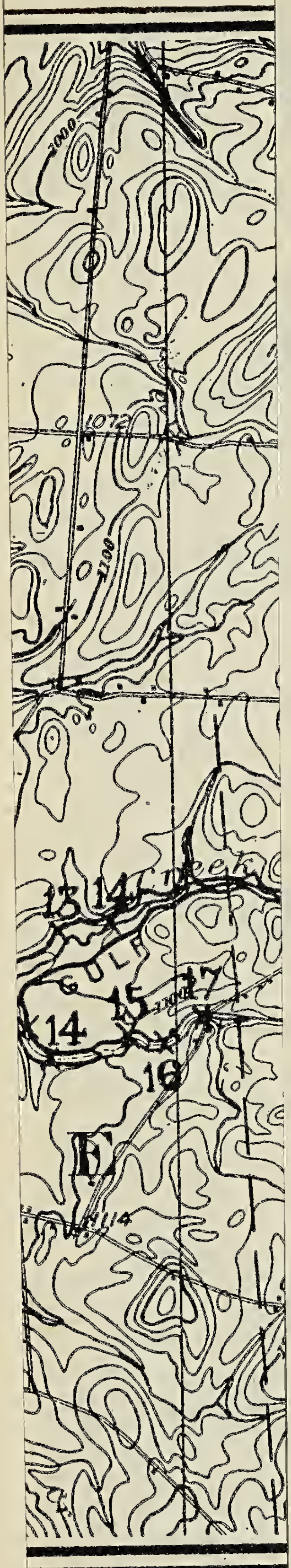


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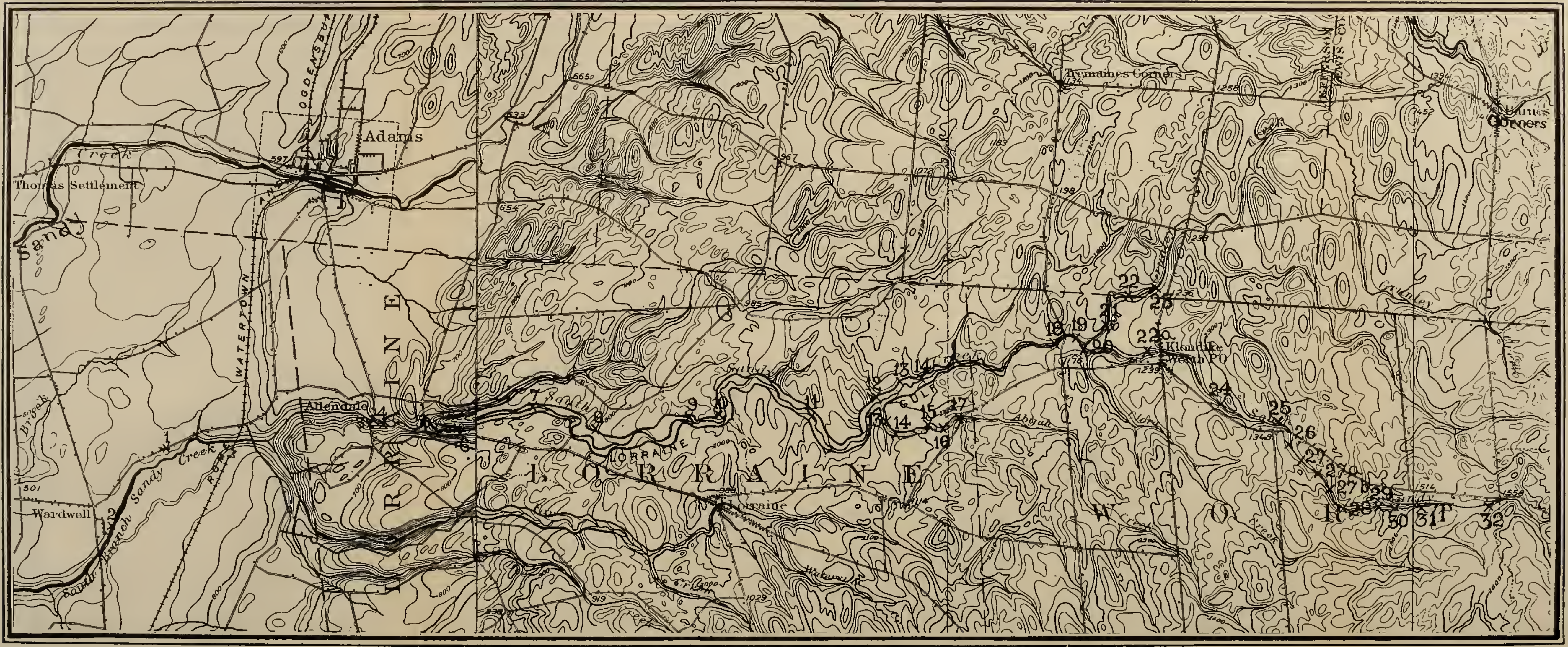
Plate 3



Map showing Stations of Lorraine Section

Station 4 (Locality number 5051). 600 feet.

Diplograptus nexus *nov.* c
†Leptobolus insignis Hall c
Zygospira modesta (Say) c
Clidophorus scitulus (Emmons) rr
*Archinacella subcarinata *nov.* rr
*Liospira micula (Hall) c
*Geisonoceras tenuitextum (Hall) rr
*Triarthrus eatoni (Hall) c
*Primitia rudis Ulrich cc
*Primitia centralis Ulrich c
*Bythocypris cylindrica Hall c

We consider this horizon, or rather the top of the preceding black shale, as the beginning of the Lorraine formation, on account of the first appearance of a number of characteristic Lorraine and Eden species.

Station 5 (Locality number 5052). 635 feet. Barren gray shales with some thin sandstone seams. One dark gray fossiliferous shale band contains:

Crinoid columnals c
Diplograptus nexus *nov.* c
*Rafinesquina ulrichi James r
Zygospira modesta (Say) cc
*Rhytimya radiata Ulrich rr
*Cryptolithus bellulus (Ulrich) cc
*Triarthrus eatoni (Hall) cc
*Primitia rudis Ulrich cc
*Bythocypris cylindrica (Hall) cc

Station 6 (Locality number 5053). 645–80 feet. Gray shale with thin layers of gray, often calcareous sandstone.

Crinoid columnals
Glossograptus quadrimucronatus lorrainensis *nov.* r
*Rafinesquina alternata centrilineata *nov.* c
Zygospira modesta (Say) c
Clidophorus scitulus (Emmons)
Colpomya intermedia *nov.*
Ctenodonta filistriata Ulrich r
Liospira micula Hall c
*Hyolithes pumilus *nov.* c
*Cornulites progressus *nov.* rr
Cryptolithus *cf.* tesselatus Green cc (with large genal spines)
Triarthrus eatoni (Hall) r
Bythocypris cylindrica Hall c
Primitia rudis Ulrich c
Bollia pulchra *nov.* cc
*Jonesella pedigera Ulrich cc
*Lepidocoleus jamesi (Hall and Whitfield) rr

Station 7 (Locality number 5054). 690 feet. Barren gray shale. A band of black shale contains:

Diplograptus nexus *nov.* c
Glossograptus quadrimucronatus lorrainensis nov. c
†Leptobolus insignis Hall r

Rafinesquina (fragment) rr
*Dalmanella *sp*
Clidophorus scitulus (Emmons)
Ctenodonta filistriata Ulrich c
Liospira micula (Hall) r
Cryptolithus bellulus Ulrich
Triarthrus eatoni (Hall) r
*Isotelus stegops Green rr
Primitia rudis Ulrich c
Bollia pulchra *nov.* c
Bythocypris cylindrica Hall c
*Aparchites minutissimus Hall c

Station 8 (Locality number 5055). 715 feet. Gray shale with a fossiliferous sandstone layer which has afforded:

Diplograptus nexus *nov.* cc
Climacograptus typicalis posterus *nov. cc*
*Zygospira cincinnatiensis Meek r
Pterinea *sp. nov.* I. r
Liospira micula (Hall) r
Cryptolithus bellulus Ulrich c
Triarthrus eatoni (Hall) c
Lepidocoleus jamesi (Hall and Whitfield) rr

Stations 9–10 (Locality number 5056). 745–80 feet. Gray shales with thin sandstone bands. Beds for the most part barren. Two bands of dark gray and black shale furnished:

Climacograptus typicalis posterus *nov.* rr
Zygospira cincinnatiensis Meek cc
Clidophorus scitulus (Emmons) c
Colpomya intermedia *nov.* r
Cryptolithus *cf.* bellulus Ulrich r
Liospira micula (Hall) cc
Triarthrus eatoni (Hall)

Station 11 (Locality number 5057). 865 feet.

Crinoid columnals cc
Dalmanella multisecta Meek rr
Plectambonites sericeus (Sow.) cc
Zygospira *cf.* cincinnatiensis Meek cc
Byssonychia vera Ulrich rr
Clidophorus scitulus (Emmons) c
Ctenodonta filistriata Ulrich rr
Sinuites cancellatus (Hall) c
Liospira micula (Hall) rr
Triarthrus eatoni (Hall)
Primitia centralis Ulrich cc
Bythocypris cylindrica (Hall) c
Lepidocoleus jamesi (Hall and Whitfield) rr

The shale of the talus of the cliffs at this horizon contains:

*Pholidops cincinnatiensis Hall cc
Plectambonites sericeus (Sow.) c
Dalmanella *sp.* r
Zygospira cincinnatiensis Meek c
Clidophorus scitulus (Emmons) c
Colpomya faba pusilla Foerste r

Stations 12–13 (Locality number 5059). 920–45 feet. Shales and thin sandstone beds, at the mouth of Abijah creek. These beds, apparently quite barren, contain, besides crinoid columnals:

Hallopora onealli sigillarioides (Nicholson)
Amplexopora persimilis Nickles
Stigmatella subsphaerica *nov.*
Plectambonites sericeus (Sow.)
Clidophorus scitulus (Emmons)
Colpomya intermedia *nov.*
Ctenodonta *cf.* filistriata Ulrich
Liospira micula (Hall)
*Triarthrus eatoni (Hall)

Station 14 (Locality number 5060). Fifteen feet higher up (960 feet) the same faunule, together with Diplograptus and Byssonychia vera was observed in a sandy layer.

Stations 15–16 (Locality number 5061). 1020–60 feet. Gray shale alternating with thin and thicker sandstone and limestone beds.

Heterocrinus columnals cc
Large flat bryozoans
*Aspidopora bellula Ulrich and Bassler MS c
*Climacograptus lorrainensis *nov.* rr
*Plectambonites rugosus (Meek) cc
*Pholidops cincinnatiensis Hall rr
Dalmanella multisecta Meek r
*Glyptorthis crispata (Emmons) r
Zygospira cincinnatiensis Meek r
Byssonychia vera Ulrich r
Clidophorus scitulus (Emmons)
Colpomya intermedia *nov.* cc

Station 17 (Locality number 5062). 1080 feet. This horizon is exposed just below the bridge over Abijah creek on the Lorraine-Worthville road. Here were obtained mostly in shale:

Arthraria *sp.* cc
Mastigograptus *cf.* gracillimus (Lesq.) rr
Diplograptus nexus *nov.* cc
Aspidopora bellula Ulrich & Bassler MS cc
Hallopora onealli sigillarioides (Nicholson) c
Escharopora pavonia (d'Orbigny) c
Crania laelia Hall rr
†Pholidops cincinnatiensis Hall r
Dalmanella fultonensis lorrainensis *nov.* cc
D. testudinaria (Dalman) cc
Glyptorthis crispata (Emmons) c
Plectambonites rugosus (Meek) c
*Modiolopsis *sp.* r
Colpomya intermedia *nov.* (m. Eden var.) c
Byssonychia vera Ulrich c
Cymatonota *sp. nov.* r
*Orthodesma postero-quadratum *nov.* c
Clidophorus scitulus (Emmons) (l. m. Eden *var.*)
*Ctenodonta pectunculoides (Hall)
*Lyrodesma *cf.* cincinnatiense Hall r
Archinacella pulaskiensis Foerste c

*Hormotoma gracilis sublaxa U. & S. c
*Sinuites granistriatus (Ulrich) rr
S. cancellatus (Hall) c
*Tetranota rugosa (Emmons) rr
*Cyrtolites ornatus Conrad c
*Actinoceras crebriseptum (Hall) r
*Isotelus stegops Green rr
†Cryptolithus bellulus Ulrich r
*Calymmene senaria meeki Foerste
Lepidoceleus jamesi (Hall and Whitfield) c

A calcareous sandstone bed just at the bridge contains:

Hallopora onealli sigillarioides (Nicholson) cc
*Stigmatella irregularis (Ulrich) r
Byssonychia vera Ulrich r
*Trocholites planorbiformis Conrad

Stations 18–19 (Locality numbers 5063–64). 1080–1120 feet. These localities are at the head of the gulf, just below the bridge on the road leading north over Sandy creek to Tremaines Corners, a mile below Worthville and above that bridge.

These beds, shales and sandstones and a 3 in. crinoidal limestone at 19 have afforded:

Mastigograptus *cf.* gracillimus (Lesq.) r
Climacograptus lorrainensis *nov.* c
*Bythopora arctipora (Nicholson) c
†Aspidopora bellula Ulrich & Bassler MS. cc
†Dalmanella *aff.* emacerata Hall c
Plectambonites rugosus (Meek) c
Modiolopsis *sp.* r
Byssonychia vera Ulrich c
*Clidophorus scitulus (Emmons) c

There is hardly any doubt that this horizon exactly corresponds to that exposed at station 17, about a mile southwest.

Station 20 (Locality number 5065). 1130 feet. On Sandy creek below Worthville. Shale and sandstone alternating with some calcareous beds, some composed of bryozoans and others of crinoid columnals.

Crinoid columnals c
*Dekayella ulrichi (Nicholson) cc (forms a thin limestone bed)
†Arthropora cleavelandi (James) c
Bythopora arctipora (Nicholson) c
Dalmanella testudinaria (Dalman) c
Glyptorthis crispata (Emmons) c
Zygospira modesta (Say) cc
*Modiolopsis r
*Byssonychia vera Ulrich c
Colpomya intermedia *nov.* cc
Clidophorus scitulus (Emmons) c
Ctenodonta pectunculoides (Hall) rr
*Archinacella *cf.* pulaskiensis Foerste rr
Cornulites progressus *nov.* r
Cryptolithus *sp.* rr
Calymmene meeki Foerste c
Bythocypris cylindrica (Hall) rr

Station 21a (Locality number 5088*c*). 1160 feet at the bifurcation. Three-quarters of a mile below Worthville there occur:

†Glyptorthis crispata (Emmons) c
Plectambonites rugosus (Meek) c
Zygospira (?) erratica (Hall) c
*Bythopora arctipora (Nicholson) c
*Byssonychia radiata Hall r
Modiodesma modiolare (Hall) c
Colpomya intermedia *nov.* r
Clidophorus planulatus (Conrad) r
*Lyrodesma cincinnatiense Hall c
Hormotoma gracilis sublaxa U. & S. c
*Lophospira abbreviata (Hall) rr
Trocholites planorbiformis Hall rr
Calymmene meeki Foerste r

Station 22a (Locality number 5088*d*). 1180 feet. A large fauna was found in a greenish gray shale exposed below the bridge at Worthville, namely:

†Diplograptus nexus *nov.* rr
Crinoid columnals cc
†Stomatopora arachnoidea (Hall) rr
Paleschara *sp.* (Atactopora ?) r
*Hallopora andrewsi (Nicholson)
†Stigmatella irregularis (Ulrich) rr
Crania laelia Hall rr
*Pholidops subtruncata Hall cc
*Trematis punctostriata Hall rr
Dalmanella testudinaria (Dalman) cc
Plectambonites rugosus (Meek) c
Zygospira (?) erratica (Hall) c
*Modiolopsis anodontoides Hall r
*Psiloconcha subovalis (Ulrich) rr
*P. *cf.* sinuata Ulrich rr.
*Cuneamya ovata *nov.* rr
C. scapha brevior Foerste r
*C. *aff.* neglecta (Meek) rr
*C. elliptica Miller rr
*Cymatonota pholadis (Conrad) rr
*Rhytimya compressa Ulrich c
Byssonychia radiata (Hall) r
Colpomya pusilla Foerste c
Clidophorus planulatus (Conrad) c
Ctenodonta pectunculoides Hall c
*Lyrodesma cincinnatiense Hall
Archinacella subcarinata *nov.* r
Cyrtolites ornatus Conrad r
*Cyclora *cf.* pulcella Miller r
*C. parvula Hall r
Liospira micula Hall r
Hormotoma gracilis (Hall) r
Actinoceras crebriseptum (Hall) r
Cornulites progressus *nov.* r
Isotelus *sp.* (free cheeks) rr
Calymmene meeki Foerste c
†Odontopleura *cf.* crosota (Locke) (free cheeks, cranidia) r
Lepidocoleus jamesi (H. & W.) c
†Aparchites minutissimus (Hall) cc
†Bythocypris cylindrica (Hall) c

Pholidops subtruncatus and Aparchites minutissimus are by far the most common fossils in this shale. Most characteristic of this horizon are, however, the lamellibranchs, among them being the most common Rhytimya compressa; and equally characteristic is the disappearance of Glyptorthis crispata, so prominent a fossil in the preceding horizons.

In heavy ledges of sandstone, just above the milldam and about 15 feet higher, Rafinesquina nasuta occurs.

Shales containing a similar fauna are well exposed along Grunley creek, a northern affluent of Sandy creek. Here were obtained in addition, up to the 1180-foot level, (stations 21–23, locality numbers 5066–67):

*Amplexopora (?) discoidea (Nicholson) c
Glyptorthis crispata (Emmons) c
Modiodesma modiolare (Conrad) r
Clidophorus planulatus Hall c
Archinacella pulaskiensis Foerste r
Lophospira bowdeni (Safford)
Cyclora parvula Hall
Sinuites cancellatus (Hall) c
Orthoceras *cf.* lamellosum Hall c
Cryptolithus lorrainensis nov. cc

The Cryptolithus was found to fill one shale bed, while Pholidops subtruncata, Plectambonites rugosus and Glyptorthis crispata are among the common fossils. Along this brook also heavy sandstone beds with ripplemarks and cross-bedding and the sandy limestone beds so characteristic of the upper Lorraine beds become conspicuous.

Above Worthville the typical upper Lorraine rocks, rusty weathering limestones and thick sandstone beds intercalated with shales are found. The outcrops, however, because of the shallowness of the valley are far apart and the section incomplete.

Station 24 (Locality number 5088*e*). 1225 feet. About one-half a mile above Worthville in a small outcrop of shale and sandstone on the bank of Sandy creek were obtained:

Crinoid columnals
*Arthropora shafferi (Meek)
Amplexopora (?) discoidea (Nicholson)
Pholidops subtruncata Hall
Byssonychia radiata (Hall)
†Lyrodesma cincinnatiense Hall
Sinuites cancellatus (Hall)
*Clathrospira subconica (Hall)
†Cornulites progressus *nov.*

Station 25 (Locality number 5088*i*). 1275 feet. Three-quarters of a mile farther up the creek a heavy gray sandstone bed (2 feet thick) calcareous sandstone and shale appear in the bank and the bed of the creek. These beds contain:

Crinoid columnals
*Bythopora dendrina (James) cc
Amplexopora (?) discoidea (Nicholson) c
Pholidops subtruncata Hall c
Plectambonites sericeus (Sow.) small, cc
Zygospira modesta (Say) c
Zygospira (?) erratica (Hall) r
Modiodesma modiolare (Conrad) c
Colpomya pusilla Foerste c
Clidophorus planulatus (Conrad) large, c
Ctenodonta pectunculoides Hall
*Ischyrodonta unionoides (Meek) c
*Lyrodesma poststriatum Hall c
*L. *cf.* planum (Conrad) rr (in outcrops 35 feet below station 25)
Cyrtolites ornatus Conrad c
Lophospira bowdeni (Stafford) cc
Actinoceras crebriseptum Hall r
*Cornulites progressus *nov.* r
Isotelus *sp. cf.* maximus pulaskiensis Ulrich MS.
†Calymmene meeki Foerste r
†Lepidocoleus jamesi (H. & W.) rr

This zone is characterized by the abundance of Bythopora dendrina and Lophospira bowdeni, the latter in the thin bed of calcareous sandstone; as well as the appearance of Ischyrodonta unionoides and Lyrodesma poststriatum and the frequency of large typical Modiodesma modiolare.

Station 26. 1310 feet. Where the road leading eastward from Worthville crosses Sandy creek thick, ripple-marked sandstone beds are exposed, which contain:

Modiodesma modiolare (Conrad)
Clidophorus planulatus (Conrad)
Actinoceras crebriseptum Hall

Station 27 (Locality number 5088*j*). 1325 feet. Small outcrops of sandstone and limestone along Sandy creek, about a quarter of a mile above the road crossing contain Modiodesma modiolare, Ischyrodonta unionoides and Lyrodesma poststriatum as the dominant fossils. Besides these occur Bythopora dendrina (James) and a large variant of Plectambonites rugosus fills a limestone band.

Station 27a. 1350 feet. This outcrop consists of gray, rusty brown weathering calcareous sandstone exposed in the bank of the creek. Some surfaces are covered with mud pebbles. The rock is very fossiliferous in certain layers and contains:

Crinoid columnals
Bythopora dendrina (James) c
Amplexopora (?) discoidea (Nicholson) r
*Rafinesquina mucronata Foerste cc
Zygospira modesta (Say) c
Zygospira (?) erratica (Hall) cc
Byssonychia radiata (Hall) c
Modiodesma modiolare (Conrad) c
*Whiteavesia nasuta (Conrad) c
Lyrodesma poststriatum (Hall) r
*Lophospira bowdeni (Safford) r

The most characteristic and also common fossils of this horizon are: Rafinesquina mucronata, Zygospira (?) erratica and Whiteavesia nasuta, the former two filling certain bands to the exclusion of other fossils.

Station 27b. 1370 feet. Several small outcrops of rusty brown weathering calcareous sandstone, full of mud pebbles, along the creek contain:

Crinoid columnals c
Arthropora shafferi (Meek) c
†Rafinesquina nasuta (Conrad) r
R. mucronata Foerste cc
Zygospira modesta (Say) r
Zygospira (?) erratica (Hall) cc
Whiteavesia nasuta (Conrad) r
†Lyrodesma poststriatum (Hall) r
†Ctenodonta pectunculoides Hall r

This station is distinctly a continuation of the horizon exposed in station *27a*.

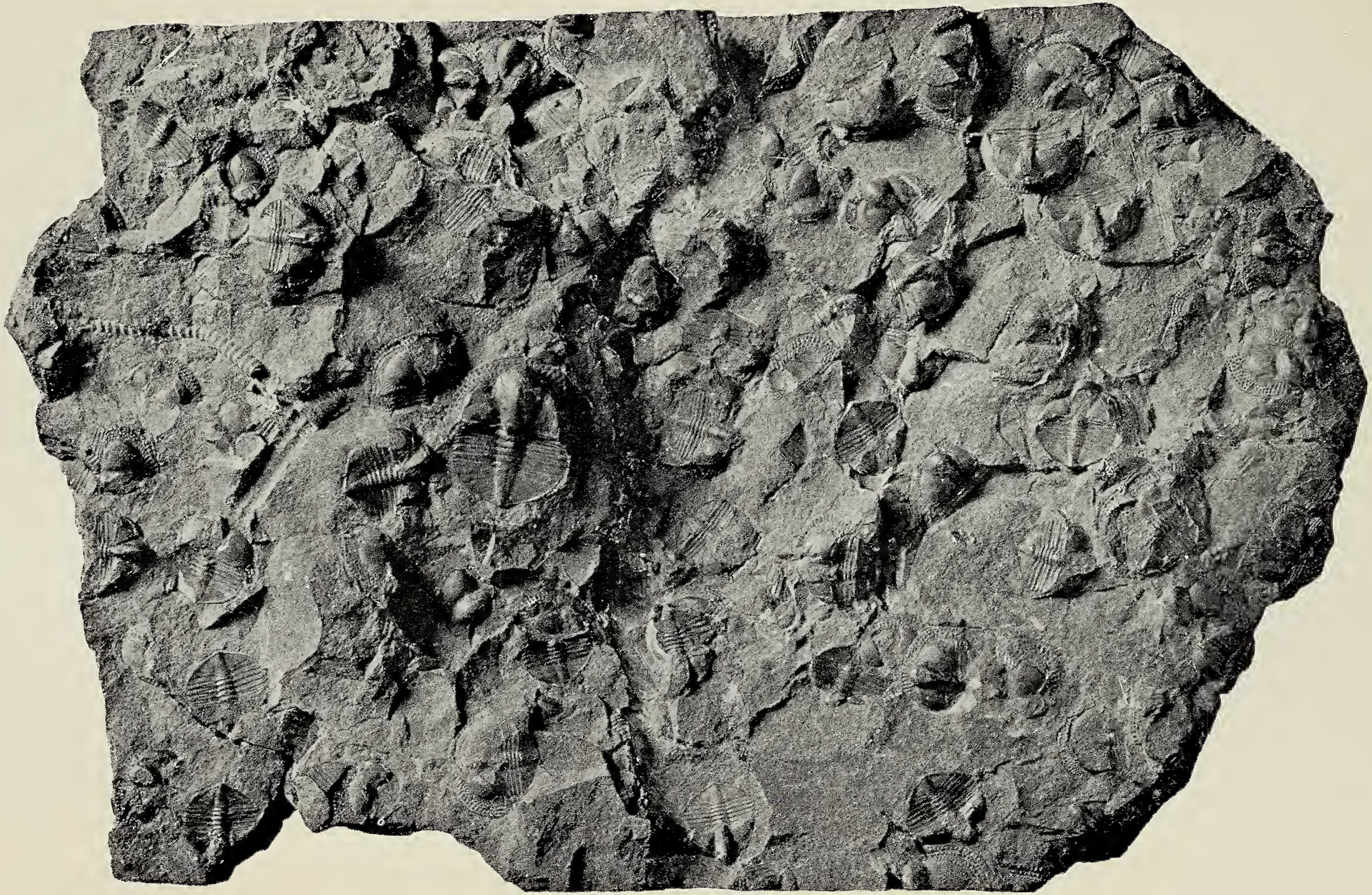
Station 28 (Locality number 5088*k*). 1390 feet. An outcrop in the bank of the creek, of gray calcareous sandstone with mud pebbles, alternating with bluish green barren shale, has afforded:

Crinoid columnals
†Arthropora shafferi (Meek)
†Pholidops subtruncata Hall
Pterinea (Caritodens) demissa (Conrad) (large specimens)
Byssonychia radiata (Hall)
†Modiodesma modiolare (Conrad)
†Whiteavesia nasuta (Conrad)
*Pholadomorpha nasuta *nov.*
Clidophorus planulatus (Conrad)
†Actinoceras crebriseptum (Hall)

The guide fossil of this horizon is Pholadomorpha nasuta *nov.*

Station 29 (Locality number 5088*l*). 1430 feet. This outcrop is just below a sawmill and consists of gray, porous sand-

Plate 4



Slab showing life of Pulaski shale. ⅔ nat. size.

stone full of iron specks and markedly approaching in aspect the Oswego sandstone. It contains:

Crinoid columnals r
Bythopora dendrina (James) c
B. *cf.* gracilis (Nicholson) r
Rafinesquina mucronata Foerste r
Byssonychia radiata (Hall) r
Pholadomorpha nasuta *nov.* r

Station 30 (Locality number 5088*m*). 1440 feet. Only 10 feet above the preceding station a like sandstone contains:

Bythopora dendrina (James) c
Rafinesquina mucronata (Foerste) cc
†Pholadomorpha nasuta *nov.* c

Rafinesquina mucronata here completely fills one layer.

Station 31 (Locality number 5088*n*). 1475 feet. This outcrop is under the dam of an abandoned sawmill, a four-foot bed of gray sandstone, underlain by barren arenaceous and argillaceous shale, forming here a low fall. The beds are becoming quite barren, a thin calcareous, rusty weathering band alone affording fossils, namely:

†Bythopora dendrina (James) c
†Amplexopora (?) discoidea (Nicholson) r
†Rafinesquina mucronata Foerste c
†Zygospira modesta (Say) r
†Zygospira erratica (Hall) r
†Caritodens demissa (Conrad) (large specimens) c
Byssonychia radiata (Hall) r
†Isotelus *sp.* (free cheek) rr

Station 32 (Locality number 1588*o*). 1500 feet. An outcrop of gray sandstone of the appearance of the Oswego sandstone, below the dam of an abandoned mill, a quarter of a mile southwest from the point where the Barners Corners road branches off from the Worthville-Martinsburg road. The fossils are here very poorly preserved and scarce. There were found:

†Byssonychia radiata (Hall)
†Clidophorus planulatus (Conrad)
†Clathrospira subconica (Hall) (fragment)

Above this outcrop the creek has not yet eroded through the drift and outcrops fail, while the hillsides are covered with slabs of Oswego sandstone, indicating the presence of this formation in close proximity.

Lorraine Village. When Emmons proposed to substitute the name " Lorraine shales " for " Pulaski shales," because at Pulaski only the upper part of the formation is exposed and at Lorraine "the whole mass, with all the relations of the inferior and superior rocks" (see Emmons, 1843, p. 119, 401), he also stated that the Lorraine formation is typically exposed "in the gulf of Lorraine, or in the adjacent country." The "Lorraine gulf" can therefore be considered as furnishing the type section. Nevertheless, it was considered of interest to establish the exact horizon of the outcrops in the village of Lorraine since modern usage makes this the typical Lorraine and investigators who wish to study the Lorraine formation first turn to this locality. Lorraine is situated at the head of the "gulf" of Fox creek; the latter runs parallel to and is a southern tributary of Sandy creek.

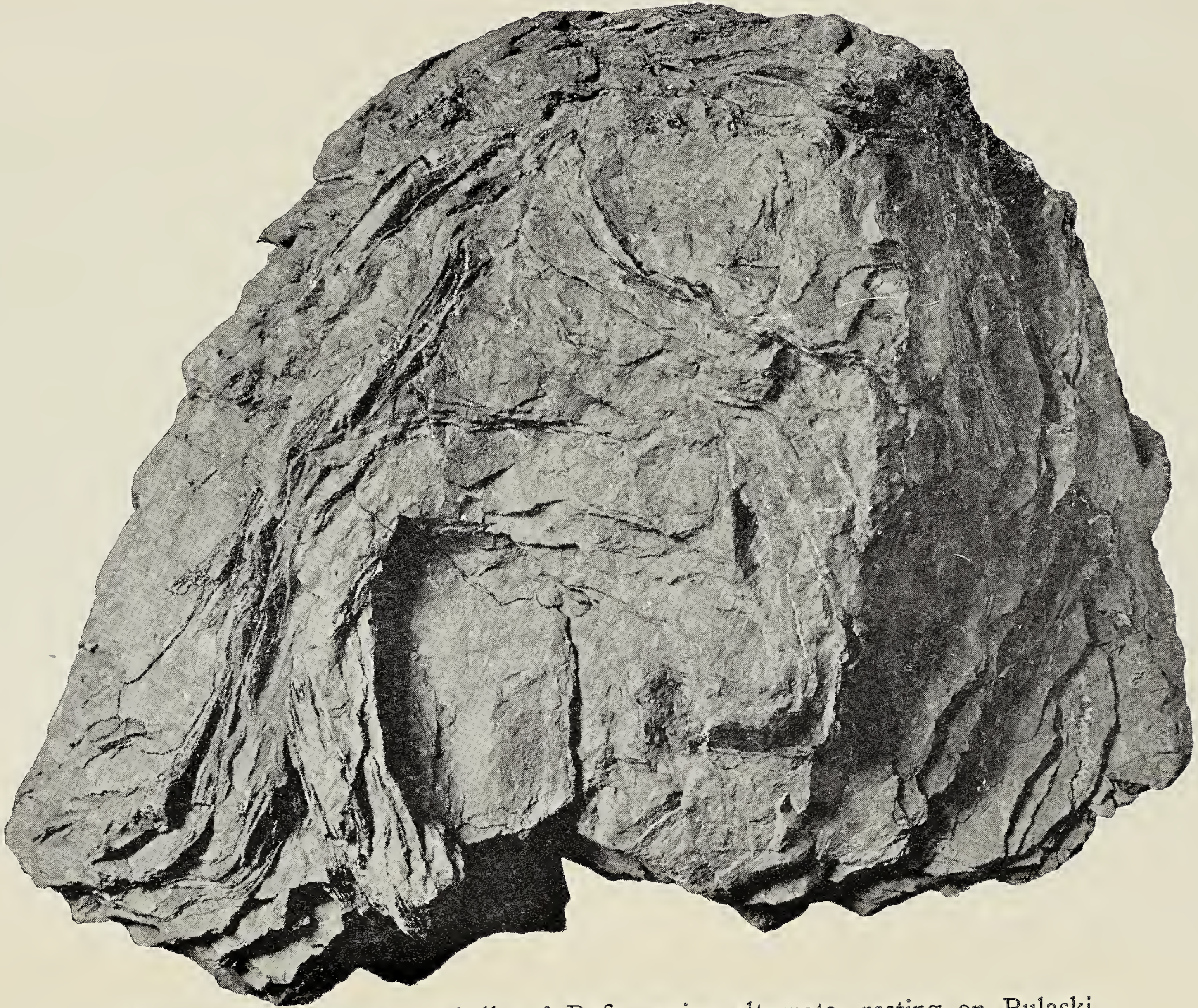
Station 1. About one-half a mile below the village or 20–30 feet below the rocks exposed under the bridge in the village the heavy sandstone beds and calcareous bands of the upper division of the Lorraine beds appear in the section. Here the Diplograptus nexus and Arthraria are the leading fossils.

Station 2. The exposures within the ravine in the village which extend to the eastern end of the village have afforded the following fauna:

Crinoid columnals
Mastigograptus *sp.* (fragments)
Climacograptus lorrainensis *nov.*
Aspidopora bellula Ulrich & Bassler
Corynotrypa delicatula (James)
Pholidops subtruncata Hall
Trematis millepunctata Hall
Rafinesquina alternata (Emmons) (small, flat form)
Dalmanella testudinaria (Dalman)
Glyptorthis crispata (Emmons)
Plectambonites rugosus (Meek)
Cornulites progressus *nov.*
Serpulites crassimarginalis Ruedemann *sp.*
†Modiolopsis praecedens *nov.*
Byssonychia radiata (Hall)
Rhytimya *sp.*
Cuneamya *aff.* neglecta (Meek)
Colpomya pusilla Foerste
Clidophorus planulatus Hall
Archinacella pulaskiensis Foerste
Cyrtolites ornatus Conrad
Hormotoma gracilis-sublaxa U. & S.
Sinuites cancellatus (Hall)
Actinoceras crebriseptum (Hall)
Trocholites planorbiformis Hall
Lepidocoleus jamesi (H. & W.)

Trematis millepunctata is very common in one bed. Foerste also records Zygospira (?) erratica, Cuneamya scapha-brevior, Ctenodonta pectunculoides and Lyrodesma poststriatum from this

Plate 5



Current-drifted mass of shells of Rafinesquina alternata, resting on Pulaski sandstone at Pulaski, N. Y. ½ nat. size.

locality. Some large blocks of impure sandstone lying by the side of the ravine, eroded out from a nearby locality were filled with specimens of Cryptolithus lorrainensis and also contained Bythopora gracilis (early form, *fide* Ulrich), Peronopora *cf.* compressa Ulrich, Lophospira abbreviata, Calymmene senaria meeki and Odontopleura crosota.

Pulaski section. The outcrops of Lorraine rocks along the Salmon river about Pulaski were well known to the geologists of the first survey and the term " Pulaski shales " as well as the earlier term " Salmon River shales " were derived from these outcrops. It has therefore been a matter of considerable importance to correlate the outcrops of Pulaski with a part of the Lorraine section and to establish their characteristic fauna. The locality for this reason has been visited by Ulrich and the writer and subsequently by Ulrich and Foerste. The last named author (1916, p. 9) has cited the following forms as found by him east of Pulaski, as far as the railway bridge:

Cornulites *sp.*
Lingula *sp.*
Schizocrania filosa
Dalmanella of testudinaria group
Plectambonites sericeus
Rafinesquina alternata
Rafinesquina nasuta
Rafinesquina mucronata
Byssonychia radiata
Colpomya faba-pusilla
Modiolopsis modiolaris
Orthodesma pulaskiense
Cymatonota pholadis
Ischyrodonta curta
Clidophorus planulatus
Lyrodesma poststriatum
Cuneamya *cf.* elliptica
Archinacella pulaskiensis
Cyrtolites ornatus
Trinucleus concentricus
Calymmene *sp.*

Foerste in a letter dated September 23, 1916 has added to this list:

Clathrospira subconica (Hall)
Sinuites cancellatus (Hall)
Lophospira bowdeni (Safford)
Actinoceras crebriseptum (Hall)
Trocholites planorbiformis (Conrad)

and material kindly sent by him also contains:

Stigmatella irregularis (Ulrich)
Whitella *sp.*

Hall has further recorded from Pulaski, in the Paleontology of New York, volume 1:

Buthotrephis subnodosa, central parts of group
Hormotoma gracilis, throughout the group
Clathrospira subconica, central parts of group
Sinuites cancellatus
Endoceras coralliferum
Paractinoceras lamellosum

To this fauna also belong the following bryozoans collected by Ulrich in the middle sandy shale of the Pulaski section, at the railroad bridge (United States National Museum locality number 282):

Arthropora *aff.* shafferi (Meek)
Bythopora dendrina (James)
Stigmatella irregularis (Ulrich)
Aspidopora *n. sp. aff.* spinulosa (Ulrich MS)
Eridotrypa *sp. aff.* minor (Ulrich MS)

The following additional species were found by the writer in the shale and sandstone under and below the bridge:

Arthraria magna *nov.*
Zygospira (?) erratica (Hall)
Pterinea (Caritodens) demissa (Conrad)
Bythocypris cylindrica (Hall)
Aparchites minutissimus (Hall)

The rocks above the bridge have afforded as further addition:

Amplexopora (?) discoidea (Nicholson) (?) (casts)
Modiolopsis lorrainensis Ulrich MS
Liospira micula (Hall)
Ceratopsis oculifera (Hall)

Two miles below or west of Pulaski a good series of outcrops is found in cliffs along the Salmon river. Here the shales are more prevalent than in the outcrops above Pulaski and the fauna would seem to indicate a lower horizon. There were found:

Crinoid columnals
Arthropora cincinnatiensis (James)
Cornulites progressus *nov.*
Byssonychia radiata Hall
Modiodesma *cf.* modiolare (Conrad)
Cymatonota parallela (Hall)
Clidophorus scitulus (Emmons)
Ctenodonta perminuta Ulrich
Calymmene *sp.*
Aparchites minutissimus (Hall)
Bythocypris cylindrica (Hall)

The outcrop of Lorraine rocks above Pulaski, extending from the beginning of the mill race to the bridge of the Rome-Watertown railroad and about an eighth of a mile beyond does not comprise more than 40 feet of rock and the faunules of the basal and top beds are not sufficiently different to indicate a difference of horizons. Nevertheless, the rocks are so accessible and give such a clear picture of the physical conditions under which these upper Lorraine beds were deposited, that they invite more elaborate description.

The formation consists of an endless alternation of shales and sandstone, the sandstone beds ranging from a few inches to a foot or more in thickness, while the shale alternations are as a rule, from 1 to 3 feet thick. Much of the rock is calcareous and often a sandstone, only about 1 foot thick, and consists either in its lower or upper half of crinoidal limestone. It is these calcareous bands which are highly fossiliferous while the pure sandstone and shale are rather barren; the shale where it is fossiliferous contains a microfauna. Some of the sandstone surfaces exhibit ripple-marks, mostly of the symmetric kind and running, when measured, in a north-northeast direction. In one case, at the base of the section, two sets intersect, producing a reticulate pattern; in another case crescent-shaped ridges, 1½ feet high, are seen, over which the ripple-marks pass. Other ripple-marks are cup shaped.

The sandstone beds frequently thin out rapidly; thus a 7-inch bed at the base dwindles to 1 inch within 8 feet. These sandstone lenses are seen to rest in depressions of the underlying rock, suggesting that they are channel fillings. This feature is especially well exhibited above the railroad bridge in the west bank of the river. There also occur lenticular masses of bryozoans, crinoid columnals and brachiopods in the sandstone, which are clearly masses swept together on the ancient sea floor. The most interesting display of shell heaps is found over a large area on the surface of a barren sandstone, where large Rafinesquinas are swept in some places into elongate heaps either arranged longitudinally, or in long strings, or again in rudely concentric fashion. In one place these drift masses of Rafinesquina form compact balls, 2 feet in diameter, consisting entirely of closely packed shells of that brachiopod in concentric arrangement (see plate 4).

All these interesting phenomena leave no doubt that the Pulaski beds were formed in shallow water and under the influence of strong and shifting currents (see p. 165).

Several sandstone, and sandy shale beds are filled with worm-burrows, among them the form described from here by Hall as Bythotrephis subnodosa and the larger peculiar type, described in part 2 as Arthraria magna.

The lower beds, below the railroad bridge, have afforded to the writer:

Bythotrephis subnodosa (Hall)
Arthraria magna
Crinoid columnals
Bythopora gracilis (Nicholson)
Stigmatella irregularis (Ulrich)
Amplexopora (?) discoidea (Nicholson)
Aspidopora *sp. nov.*
Stigmatella pulaskiensis *nov.*
Leptotrypa minima Ulrich
Atactopora hirsuta Ulrich
A. maculata Ulrich
Dalmanella testudinaria (Dalman)
Rafinesquina alternata (Emmons)
R. nasuta (Conrad)
Plectambonites sericeus (Sow.)
Zygospira (?) erratica (Hall)
Cornulites progressus *nov.*
Pterinea (Caritodens) demissa (Conrad)
Byssonychia radiata (Hall)
Modiodesma modiolare (Conrad)
Colpomya pusilla Foerste
Cymatonota parallela (Hall)
Clidophorus planulatus Hall
Ischyrodonta unionoides (Meek)
Lyrodesma poststriatum Hall
Archinacella pulaskiensis Foerste
Cyrtolites ornatus Conrad
Sinuites cancellatus Hall
Lophospira bowdeni (Safford)
Clathrospira subconica (Hall)
Actinoceras crebriseptum (Hall)
Cryptolithus lorrainensis *nov.*
Calymmene *cf.* senaria meeki Foerste
Bythocypris cylindrica (Hall)
Aparchites minutissimus (Hall)

There are further recorded by Foerste from these beds:

Lingula *sp.*
Schizocrania filosa *Hall*
Rafinesquina mucronata *Foerste*
Orthodesma pulaskiense *Foerste*
Cuneamya *cf.* elliptica *Miller*
Trocholites planorbiformis (*Conrad*)

The beds above the railroad bridge, mainly calcareous sandstone were found to contain in the sandstone:

Bythotrephis subnodosa Hall
Arthraria *sp.*
Crinoid columnals
Atactopora *cf.* hirsuta Ulrich
Arthropora cincinnatiensis James
Bythopora gracilis Nicholson
Amplexopora (?) discoidea (Nicholson)
Rafinesquina nasuta (Conrad)
Dalmanella testudinaria (Dalman)
Plectambonites sericeus (Sow.)
Zygospira modesta Hall

Zygospira (?) erratica (Hall)
Cornulites progressus *nov.*
Pterinea (Caritodens) demissa (Conrad)
Byssonychia radiata (Hall)
Modiodesma modiolare (Conrad)
Cymatonota pholadis Hall
Clidophorus planulatus Hall
Ischyrodonta unionoides (Meek) cc
Lyrodesma poststriatum Hall cc
Cyrtolites ornatus Conrad
Actinoceras crebriseptum (Hall)
Cryptolithus lorrainensis *nov.*
Isotelus maximus pulaskiensis Ulrich MS
Calymmene *cf.* senaria meeki Foerste
Ceratopsis oculifera (Hall) c

The rather barren shale has furnished:

Clidophorus planulatus Hall
Cymatonota parallela Hall
Colpomya pusilla Foerste
Cyrtolites ornatus Conrad
Liospira micula (Hall) cc
Calymmene *cf.* senaria meeki Foerste

Material in the United States National Museum contains also Odontopleura crosota Locke.

The relation of the Pulaski faunules to those observed in the Lorraine section will be discussed on pages 128, 133.

Lower Lorraine fauna near Rome. There are also in the State Museum and the United States National Museum collections of fossils from the lower Lorraine shale, in the Rust purchases, obtained by Mr C. Valiant, the discoverer of the appendages of Triarthrus eatoni. They contain several forms not observed in other association, and the fauna, which apparently was collected in one bed, is therefore here given:

Climacograptus typicalis Hall (large)
Heterocrinus heterodactylus Hall, emend. Ulrich
Stomatopora arachnoidea (Hall)
Proboscina *sp.*
Corynotrypa delicatula (James)
Arthropora cleavelandi (James)
Hallopora onealli (James)
Crania laelia Hall
Lingula curta Conrad
Zygospira modesta (Say)
Pterinea *sp. nov.* no. 1.
Prolobella corrugata *nov.*
Byssonychia vera Ulrich
Cymatonota parva Miller
Whiteavesia *sp. nov* 1
Rhytimya radiata Ulrich
Colpomya intermedia *nov.*
Cymatonota parallela (Hall)
Ctenodonta filistriata Ulrich (common)
Sinuites granostriatus Ulrich
Liospira micula (Hall)

L. *cf.* americana (Billings)
Trochonema *sp.*
Triarthrus eatoni Hall
Bythocypris cylindrica Hall
Isotelus stegops Green
Cryptolithus bellulus Ulrich (very common)
Gerasaphes ulrichana Clarke
Bollia pulchra *nov.*

The first locality of the Pulaski formation in the Mohawk valley is also near Rome. Vanuxem (1842, p. 66) mentions "Talcott's and Comstock's quarries about 2 miles to the south of Rome" as the first occurrences of the "sandstone shale of Pulaski," saying that about 10 feet of the mass is exposed, the larger portion of which is good building stone and is quarried for Rome. These quarries are mentioned in a number of descriptions of Pulaski fossils by Conrad and Hall.

Regarding these quarries Foerste writes that he thoroughly searched all the country southeast of Rome within an area of 4 miles, and came to the conclusion that the Comstock quarry which furnished most fossils to Conrad probably occurred in the creek bed immediately south of Dix, while the Talcott quarry was situated in another creek bed about a mile west of Dix. He found south of Dix (letter of Sept. 23, 1916):

Rafinesquina mucronata Foerste
Dalmanella *sp.*
Modiolopsis modiolaris (Conrad)
Ischyrodonta curta (Conrad)
Cymatonota pholadis (Conrad)
Clidophorus planulatus Hall
Sinuites cancellata (Hall)
Cyrtolites ornatus Conrad
Lophospira bowdeni (Safford)

This is a typical Pulaski fauna corresponding to that found at Pulaski village above and below the railroad bridge.

Also the Oswego sandstone makes its first appearance near Rome, where, according to Vanuxem (*op. cit.* p. 68) it was formerly obtained to the southwest of the city in Woodruff's quarry. This quarry has also stopped operation long ago and is no more known, but the sandstone is exposed on the road from Rome to Verona.

It is thus seen that all divisions of the Lorraine, the Whetstone Gulf shale, the Pulaski shale and sandstone, and the Oswego sandstone, appear rather abruptly, only within 12 to 15 miles from Utica, where any trace of them is lacking between the Frankfort and Medina beds; and exhibit at once such strong development, especially in the case of the Whetstone Gulf shale, as to suggest their former (pre-Medinan) extension eastward for some distance.

Lorraine fauna in drift. A large portion of the Lorraine fauna of New York is best known from the drift. This is due to the fact that the calcareous sandstone of the upper Lorraine or Pulaski beds, which is the fossiliferous rock of the formation, is so hard that it is practically impossible to obtain entire fossils from the fresh rock. Similarly, as in the Schoharie grit and Oriskany sandstone of New York, the rock on weathering loses the calcareous matrix and becomes altered into a rusty brown porous sandstone in which the exterior and interior molds of the fossils are beautifully preserved.

Walcott (1890, p. 347) has already given a long list of fossils which he obtained from the drift. The large collections of drift material in the United States National Museum and the State Museum, mostly from the Rust collection contain the following forms:

Stomatopora arachnoidea (Hall)
Amplexopora (?) discoidea (Nicholson)
Bythopora gracilis (Nicholson)
Atactopora hirsuta Ulrich
Atactopora maculata Ulrich
Pholidops subtruncata Hall
Dalmanella testudinaria (Dalman)
Hebertella occidentalis (Hall)
Rafinesquina alternata (Emmons)
R. alternata alternistriata (Hall)
R. nasuta (Conrad)
R. mucronata Foerste
Plectambonites sericeus (Sow.)
Leptaena richmondensis Foerste
Zygospira modesta (Hall)
Zygospira (?) erratica (Hall)
Cornulites progressus *nov.*
Pterinea (Caritodens) demissa (Conrad)
Byssonychia radiata (Hall)
Rhytimya obesa *nov.*
Modiodesma modiolare (Conrad)
Modiolopsis ovata (Conrad)
Modiolodon obtusus *nov.*
Whiteavesia nasuta (Hall)
Orthodesma transitum Ulrich
O. pulaskiense Foerste
O. *cf.* corryvillense Ulrich
O. *cf.* extensum Ulrich
Cymatonota parallela (Hall)
C. parallela (Hall) *var.*
C. pholadis (Conrad)
C. (?) (Orthodesma) prolatum Foerste
Psiloconcha subovalis (Ulrich)
P. acclivis *nov.*
P. *cf.* sinuata Ulrich
Colpomya pusilla Foerste
Clidophorus planulatus Hall
Ctenodonta pectunculoides Hall
Whiteavesia *sp. nov.*
Ischyrodonta unionoides (Meek)

Lyrodesma poststriatum Hall
Cyrtolites ornatus Conrad
Cyclora *cf.* minuta Hall
Liospira micula (Hall)
Lophospira bicincta (Hall)
L. tropidophora (Meek)
Clathrospira subconica Hall
Paractinoceras pusillum *nov.*
Orthoceras *sp.*
Cryptolithus lorrainensis *nov.*
Calymmene *cf.* senaria meeki Foerste
Isotelus maximus pulaskiensis Ulrich MS

The most interesting feature of this drift material is the frequency of boulders filled with Rafinesquina mucronata and Zygospira (?) erratica, the latter form having received its name from this mode of occurrence. Also Ischyrodonta unionoides, Lyrodesma poststriatum, Rafinesquina nasuta, Pterinea, demissa and Modiodesma modiolare are found more frequently and in better specimens in the drift than can be found in the rock outcrops, and they are usually associated with Zygospira (?) erratica. These assemblages of species indicate that the largest portion of the drift comes from the highest horizon of the Lorraine, save the last with Pholadomorpha, but since Walcott also records Modiolopsis pholadiformis from the drift, this horizon is undoubtedly represented. Naturally only the hardest rocks of the Lorraine formation, namely, the calcareous sandstones of the last horizons appear in the drift.

HORIZONS OF LORRAINE GROUP AND THEIR CORRELATION

The fossils found in the various sections of the Lorraine beds have been tabulated in the chart appended to part 3.

In the last column the occurrence and range of the fossils outside of New York is given after Bassler's Bibliographic Index and Foerste's Upper Ordovician Formations in Ontario and Quebec. It is at once obvious, from a perusal of this column, that the majority of the fossils occur in the Eden and Maysville groups of the Ohio basin, which through the careful paleontologic and stratigraphic work of E. O. Ulrich, A. F. Foerste, Ray S. Bassler, J. M. Nickles, E. R. Cumings and others, has become the standard region for the Upper Ordovician. The general relationship of the lower and upper Lorraine faunas of the Lorraine gulf to the Eden and Maysville faunas of the Ohio basin had already been clearly recognized by Ulrich, Foerste and the writer in their excursions to the

Lorraine region;[1] Ulrich having been able to recognize a Southgate fauna in the upper part of the lower Lorraine shales on a joint trip with the author through the Lorraine gulf.

We have in the chapters on the Utica and other black shales mentioned that the Atwater shale at Allendale, which forms the base of the Lorraine section may be of Fulton age and thus correspond to the base of the Eden section at Cincinnati. By the following lists of guide fossils of the Eden found in the various Lorraine sections of New York, it will be seen that also the two succeeding Eden members, the Economy beds and the Southgate beds are unmistakably present, while the third, the McMicken is not so distinctly developed. There are, however, also distinctive fossil elements present; for this reason we have distinguished the zones by their characteristic fossils instead of directly transferring the formation names of the Ohio basin to them.

Zone I of Cryptolithus bellulus and Bollia pulchra contains the following forms restricted to or commonly found in the Economy beds of the Cincinnati section:[2]

Rafinesquina ulrichi Hall and Clarke: Lorraine gulf 5; Mill creek 10
Clidophorus ellipticus Ulrich: Lorraine gulf 4; Whetstone gulf 6; Mill creek 8, 9; Moose creek 8, 9; Wood creek 1
Primitia rudis Ulrich: Lorraine gulf 4, 5, 6, 7; Whetstone gulf 6, 7, **9**
Jonesella pedigera Ulrich: Lorraine gulf 6
Cryptolithus bellulus Ulrich: Lorraine gulf 5, 7, 8, **9–10**; Whetstone gulf 5, 6, 7, 8, **9**; Mill creek 10, 11; Moose creek 8, 9, **10**; Wood creek, 1, 2, 3

There should be added to this list Primitia centralis Ulrich which occurs only in the Lorraine gulf 4, **5**, 6, 7, **11** and Wood creek 3. According to Nickles, it is mainly restricted to the earliest Eden (Fulton and Economy) although, according to Bassler, it ranges from the Trenton to the Maysville. Its restriction and common occurrence in the lowest Lorraine beds is thus also indicative of their Economy age.

Besides the guide fossils cited there are found in this zone:

Mastigograptus *cf.* gracillimus Lesq.: Wood creek 1, 2
Diplograptus nexus *nov.*: Lorraine gulf 4, 5, 7, **8**; Whetstone gulf 5, 6, 8; Mill creek 10, 11; Moose creek 8, 9, 10; Wood creek 1
Climacograptus pygmaeus *nov.*: Whetstone gulf 5, 6; Mill creek 8; Moose creek 8
Climacograptus typicalis posterus *nov:* Lorraine gulf **6**, 8, 9, 10; Whetstone gulf 5; Moose creek 9
Glossograptus quadrimucronatus Hall: Moose creek 8

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[1] See Ulrich, Revision, p. 511; Ulrich, 1913, p. 623; Foerste, 1914, p. 251; 1916, p. 30.

[2] The numbers give the stations of the section; those in heavy print indicate that the species is very common there.

Glossograptus quadrimucronatus lorrainensis *nov.* Lorraine gulf 7
Heterocrinus propinquus Meek: Wood creek 1, 2, 3
Corynotrypa inflata (Hall): Wood creek 1
Corynotrypa delicatula (James): Wood creek 1, 3
Stomatopora arachnoidea (Hall) Wood creek 1
Paleschara bassleri *nov.:* Wood creek 1
Hallopora onealli sigillarioides James: Wood creek 1
Arthropora cleavelandi (*James*): Whetstone gulf 5, 7, 9; Wood creek 1, 3
Leptobolus insignis Hall: Lorraine gulf 4, 7; Whetstone gulf 5
Trematis millepunctata Hall: Whetstone gulf 7
Pholidops cincinnatiensis Hall: Whetstone gulf 7, 9; Mill creek 10
Rafinesquina alternata centrilineata: Lorraine gulf 6; Whetstone gulf 8, 9
Dalmanella emacerata Hall: Whetstone gulf 9
Dalmanella multisecta (Meek): Whetstone gulf 7
Zygospira modesta (Say): Lorraine gulf 4, 5, 6, 8, 9, 10; Whetstone gulf 5, 7, 9; Mill creek 1, 2, 3
Arthrariella lorrainensis *nov.:* Whetstone gulf 9
Hyolithes pumilus *nov.:* Lorraine gulf 6; Whetstone gulf 6
Pterinea rotunda *nov.:* Lorraine gulf 8; Whetstone gulf 9; Mill creek 10; Wood creek 1
Pterinea sublata *nov.:* Wood creek 1
Byssonychia vera Ulrich: Whetstone gulf 8, 9; Wood creek 1, 3
Cymatonota parallela (Hall): Whetstone gulf 7
Rhytimya radiata Ulrich: Lorraine gulf 5; Whetstone gulf 7; Wood creek 1, 3
Whiteavesia subplana *nov.:* 1: Wood creek 1
Cuneamya rugata *nov.:* Whetstone gulf 6
Clidophorus scitulus (Emmons): Whetstone gulf 6, 7, 9, 10; Mill creek 10; Moose creek 8, 9; Wood creek 1, 2, 3
Colpomya faba pusilla Foerste: Lorraine gulf 6, 9, 10; Whetstone gulf 5; Mill creek 10
Ctenodonta filistriata Ulrich: Lorraine gulf 6, 7; Whetstone gulf 5; Mill creek 9, 10; Wood creek 1, 2, 3
Ctenodonta pectunculoides Hall: Whetstone gulf 9
Archinacella subconvexa *nov.:* Lorraine gulf 4; Mill creek 10; Wood creek 2
Sinuites cancellatus (Hall): Wood creek 1
Sinuites granistriatus (Ulrich): Whetstone gulf 9; Wood creek 1
Sinuites planodorsatus (Ulrich): Moose creek 9; Wood creek 1
Liospira micula (Hall): Lorraine gulf 4, 6, 7, 8, 9, 10; Whetstone gulf 5, 6, 9; Mill creek 9; Moose creek 8, 9; Wood creek 2
Plethospira quadricarinata *nov.:* Wood creek 1
Cornulites progressus *nov.:* Lorraine gulf 6; Wood creek 1
Actinoceras *cf.* lamellosum Hall: Mill creek 9; Moose creek 9
Cryptolithus bellulus Ulrich: Lorraine gulf 6; Wood creek 2
Triarthrus eatoni (Hall): Lorraine gulf 4, 5, 6, 7, 8, 9, 10; Whetstone gulf 5, 6, 7, 9; Mill creek 9, 10, 11; Moose creek 9, 10; Wood creek 1, 2
Isotelus stegops Green: Whetstone gulf 9; Mill creek 11; Moose creek 9; Wood creek 1, 3
Calymmene senaria granulosa Foerste: Whetstone gulf 6, 7, 9; Wood creek 1, 2, 3
Odontopleura crosota (Locke): Whetstone gulf 6, 7, 9; Mill creek 10; Wood creek 2, 3
Aparchites minutissimus (Hall): Lorraine gulf 7; Whetstone gulf 5, 6, 7, 9; Mill creek 10; Moose creek 9; Wood creek 2
Bythocypris cylindrica (Hall): Lorraine gulf 4, 5, 6, 7; Whetstone gulf 6, 7, 9; Mill creek 10; Wood creek 3

Bollia pulchra *nov.:* Lorraine gulf 6, 7; Whetstone gulf 6; Mill creek 9, 10; Moose creek 9; Wood creek 1, 2

Lepidocoleus jamesi (H. & W.): Lorraine gulf 6, 8; Whetstone gulf 7, 9; Mill creek 10; Moose creek 10; Wood creek 1, 2, 3

It will be noted, in analyzing this list, that besides a considerable number of new forms and many long range forms, there are a number of types which enter this formation from below and disappear so soon that they serve to indicate the close position of the horizon to the Utica beds. These are especially the graptolite species Climacograptus pygmaeus; Climacograptus typicalis posterus and Glossograptus quadrimucronatus; also Leptobolus insignis, which is a Utica and Fulton form, and Triarthrus eatoni. On the other hand, there appear in this zone a few species which in the Ohio basin are restricted to the following, the Southgate, formation, (according to Bassler's Index). These are Rhytimya radiata, Sinuites granistriatus and planodorsatus. All of these find, however, their principal development in the following zone and most of them were found in the basal beds of the Wood creek section (Station 1–3), the southernmost exposure of the lower Lorraine shales. It is, however, in this section that the base of the Southgate would seem to be well fixed by the occurrence at station 4, of Aspidopora bellula and Lyrodesma conradi. We can then but conclude that owing to the considerable difference in geographic position, the ranges of the fossils are not exactly identical in the two regions.

From the faunal evidence here cited, we would correlate with the Economy formation, stations 4–10 of the Lorraine section; stations 5–9 of the Whetstone gulf section; stations 8–11 of the Mill creek section; stations 8–10 of the Moose creek section and stations 1–3 of the Wood creek section. The beds carrying this fauna thicken rapidly northward from Wood creek, where only 30 feet are exposed, with the base not shown, through 100–170 feet exposed in the Mill creek-Moose creek region, to 200–260 feet suggested by the Lorraine and Whetstone gulf sections which are opposite each other on the northernmost portion of the Tuck Hill plateau.

Zone II of Dalmanella emacerata and Plectambonites rugosus. The following Southgate guide fossils of the Cincinnati region occur in this zone:

Aspidopora bellula Ulrich and Bassler MSS: Lorraine gulf 15–16; Wood creek 4

Dalmanella emacerata Hall (Fulton–Southgate): Lorraine gulf 11; Whetstone gulf 9, 10–11

Rhytimya radiata Ulrich: Mill creek **15**
Lyrodesma conradi Ulrich: Wood creek 4, 8, 9
Sinuites granistritatus (Ulrich): Wood creek 8
Sinuites planodorsatus (Ulrich): Wood creek 9
Trochonema nitidum Ulrich: Moose creek 11-12

To this should be added as the most characteristic fossil of the zone, a large, broad, subrectangular mutation of Plectambonites rugosus, here for the sake of distinction termed *mutatio* major, which was recognized in the gulf section by Ulrich, on our joint trip, as a characteristic Southgate form.

Other fossils found in this zone are:

Mastigograptus *cf.* gracillimus Lesq.: Wood creek 8
Diplograptus nexus *nov.:* Lorraine gulf 14; Whetstone gulf 10–12; Mill creek 12
Climacograptus pygmaeus *nov.:* Mill creek 12
Climacograptus lorrainensis *nov.:* Lorraine gulf 15–16
Corynotrypa delicatula (James): Mill creek 12
Stomatopora arachnoidea (Hall): Wood creek 9
Hallopora onealli sigillarioides (James): Mill creek 13; Moose creek 11–12; Wood creek 6, 8, 9
Hallopora onealli (James): Wood creek 5
Arthropora cleavelandi (James): Whetstone gulf 12; Wood creek 4, 9, 10
Pholidops cincinnatiensis Hall: Lorraine gulf 15–17; Mill creek 15; Wood creek 9
Rafinesquina alternata centrilineata *nov.:* Mill creek 12; Wood creek 6, 7, 8, 9
Plectambonites sericeus (Sow.): Lorraine gulf **17–19**; Whetstone gulf 12, 13; Wood creek 10
Plectambonites rugosus (Meek): Lorraine gulf 15–16; Whetstone gulf **10–11**
Dalmanella multisecta (Meek): Lorraine gulf 11; Mill creek 15; Wood creek 12
Glyptorthis crispata (Emmons): Lorraine gulf 15–17
Zygospira modesta (Say): Lorraine gulf 11, 15–16; Mill creek 12; Wood creek **4**, 6, **8**, **10**
Zygospira concentrica Ulrich: Mill creek **12**, 13
Pterinea *sp. nov.* 1: Wood creek 9
Byssonychia vera Ulrich: Lorraine gulf 11, 14, 15–16, Whetstone gulf 8, 9, 10–11: Wood creek 4, 5, 6, 7, 8, 9
Byssonychia radiata (Hall): Whetstone gulf 10–11; Mill creek 12, 13
Cymatonota parallela (Hall): Whetstone gulf 10–11; Wood creek 8, 9
Whiteavesia subplana *nov.:* 1; Wood creek 9
Whiteavesia foerstei *nov.:* 2; Wood creek 9
Colpomya intermedia *nov.:* Lorraine gulf 12–13, 14, **15–16**, Whetstone gulf 10–11, 12, 13; Mill creek 12, 15; Moose creek 11, 12; Wood creek 8–10
Rhytimya *sp. nov.:* Mill creek 12; Moose creek 11–12; Wood creek 8
Clidophorus planulatus Hall: Whetstone gulf **12**; Mill creek 12, 15; Wood creek 10
Clidophorus scitulus (Emmons): Lorraine gulf 11, 14; Whetstone gulf 10, 11; Mill creek 12, 15; Moose creek 11–12; Wood creek 8, **9**
Ctenodonta filistriata Ulrich: Lorraine gulf 11, 12–13, 14; Mill creek, 12, 15; Moose creek 11–12; Wood creek 4, 7
Ctenodonta pectunculoides Hall: Whetstone gulf 9, 10–11
Sinuites cancellatus (Hall): Lorraine gulf 11

Liospira micula (Hall): Lorraine gulf 11, 12–13; Mill creek 12; Wood creek 10
L. vitruvia (Billings): Mill creek 12; Wood creek 10
Clathrospira subconica (Hall): Wood creek 9
Plethospira quadricarinata *nov.*: Mill creek 12; Wood creek 4, 6, 8, 9, 10
Lophospira abbreviata (Hall): Whetstone gulf 12; Mill creek 12
Cyrtolites ornatus Conrad: Whetstone gulf 12; Mill creek 12, 15; Wood creek, 6, 9
Cornulites progressus *nov.*: Whetstone gulf 12
Arthraria *sp.* Whetstone gulf 10–11
Actinoceras *cf.* lamellosum *Hall:* Whetstone gulf 10–11; Wood creek 6
Calymmene senaria meeki Foerste: Whetstone gulf 10–11, 12
C. senaria granulosa Foerste: Mill creek 12, 15; Wood creek 4, 6, 8, 9
Cryptolithus bellulus Ulrich: Moose creek 11–12; Wood creek 4
Triarthrus eatoni (Hall): Lorraine gulf 11, 12–13, 14; Mill creek 12; Moose creek 11–12; Wood creek 8
Isotelus stegops Green: Mill creek 12; Moose creek 11–12; Wood creek 4, 8, 9, 10
Odontopleura crosota (Locke): Mill creek 15; Wood creek, 4, 9
Aparchites minutissimus (Hall): Mill creek 12; Wood creek 4, 8, 9, 10
Bythocypris cylindrica (Hall): Lorraine gulf 11; Mill creek 12; Wood creek 8, 9, 10
Primitia centralis Ulrich; Lorraine gulf 11
Lepidocoleus jamesi (H. & W.): Lorraine gulf 11–16; Whetstone gulf 12; Moose creek 11–12; Wood creek 4, 9

As with the first zone, the analysis of this fauna shows that besides the guide fossils of the Southgate beds, there are here cited a considerable number of long range species of wide distribution and no special stratigraphic significance; further a few new species and finally also certain types which we would not expect as early and which, in part at least, appear much later in the Ohio region are among the prevalent forms of the Pulaski beds. Such are the Maysville forms: Glyptorthis crispata, Cymatonota pholadis, Clidophorus planulatus, Hormotoma gracilis, Lophospira abbreviata, Cyrtolites ornatus, all of which find their principal development not until the Pulaski stages. These, together with the new forms, some of which, as Whiteavesia subplana, are extremely common at certain horizons, and the absence of many characteristic Southgate species, give zone II a faunal aspect that is sufficiently different from that of the Southgate of the Ohio basin and indicate the existence of certain paleogeographic connections later to be discussed.

From the faunal evidence here cited we would correlate with the Southgate formation, stations 11–16 of the Lorraine gulf section; stations 10–13 of the Whetstone gulf section; stations 12–15 of the Mill creek section; stations 11–12 of the Moose creek section, and stations 4–10 of the Wood creek section. The thickness of the zone amounts to about 150 feet (160 feet at Moose creek, 145 feet in Whetstone gulf and 150 feet in Lorraine gulf).

Zone III of Dekayella ulrichi and Arthropora cincinnatiensis

The fauna of this zone has been observed only in the Lorraine section and below Pulaski. It is contained in rather weak fossiliferous shales with some limestone bands, alternating with thicker, but mostly barren sandstones; and is therefore not well exposed in the ravines. The zone as represented by stations 17–20 of the Lorraine section has afforded the following fossils:

Mastigograptus *cf.* gracillimus Lesq.: Lorraine gulf 17–19
Climacograptus lorrainensis *nov.:* Lorraine gulf 17–19
Escharopora pavonia (d'Orbigny): Lorraine gulf 17
Bythopora arctipora (Nicholson): Lorraine gulf 18–19
Dekayella ulrichi (Nicholson): cc, forming thin limestone bed in zone 20
Aspidopora bellula Ulrich: Lorraine gulf 17–19
Arthropora cleavelandi (James): Lorraine gulf 20
Pholidops cincinnatiensis Hall: Lorraine gulf 17
Rafinesquina alternata (Emmons): Lorraine gulf 17–19
Plectambonites sericeus (Sow.): Lorraine gulf 17–19
P. rugosus (Meek): Lorraine gulf 17–21a
Dalmanella testudinaria (Dalman): Lorraine gulf 20
D. fultonensis lorrainensis *nov.:* Lorraine gulf 17
Glyptorthis crispata (Emmons): Lorraine gulf 17–20
Zygospira modesta (Say.): Lorraine gulf 20
Byssonychia vera Ulrich: Lorraine gulf 17–20
Colpomya intermedia *nov.:* Lorraine gulf 17–19
C. pusilla Foerste: Lorraine gulf 20
Orthodesma *sp. nov.:* Lorraine gulf 17
Modiolopsis *aff.* concentrica H. & W.: Lorraine gulf 17–20
Ischyrodonta unionoides (Meek): Lorraine gulf 17–19
Clidophorus planulatus (Hall): Lorraine gulf 20
C. scitulus (Emmons): Lorraine gulf 17–19
C. pectunculoides Hall: Lorraine gulf 17, 20
Lyrodesma cincinnatiense Hall: Lorraine gulf 17
Archinacella pulaskiensis Foerste: Lorraine gulf 17, 20
Bellerophon lorrainensis *nov.:* Lorraine gulf 17
Sinuites cancellatus (Hall): 17–19
S. granistriatus (Ulrich): Lorraine gulf 17
Hormotoma gracilis (Hall): Lorraine gulf 17–19
Cyrtolites ornatus Conrad: Lorraine gulf 17–19
Cornulites progressus *nov.:* Lorraine gulf 20
Cryptolithus lorrainensis *nov.:* Lorraine gulf 18, 20
Calymmene senaria meeki Foerste: Lorraine gulf 17, 20
Isotelus stegops Green: Lorraine gulf 17
Lepidocoleus jamesi (H. & W.): Lorraine gulf 17
Bythocypris cylindrica (Hall): Lorraine gulf 20

To this zone belongs further the outcrop in the cliffs of Salmon river, 2 miles below Pulaski. Here in alternating shales and sandstones are found:

Crinoid columnals
Arthropora cincinnatiensis (James)
Cornulites progressus *nov.*

Byssonychia radiata Hall
Modiodesma modiolare (Conrad)
Cymatonota parallela (Hall)
Clidophorus scitulus (Emmons)
Ctenodonta perminuta Ulrich
Calymmene *sp.*
Aparchites minutissimus (Hall)
Bythocypris cylindrica (Hall)

This zone, about 70 feet thick in the Lorraine gulf, can not apparently be directly correlated with any of the Cincinnati zones. It holds in the Lorraine section the place corresponding to the last Eden zone, the McMicken, and also contains such fossils as Dekayella ulrichi that are quite characteristic of the McMicken. On the other hand, there appears such a number of Pulaski or Maysville forms, as Escharopora pavonia, Modiodesma modiolare, Ischyrodonta unionoides, etc., that the zone has to be considered as rather the beginning of the Pulaski (Maysville), than the end of the Whetstone Gulf formation or of the Eden portion of the section.

The outcrop below Pulaski contains in Arthropora cincinnatiensis (James) a characteristic Mount Hope form and in Byssonychia radiata, Modiodesma modiolare and Cymatonota parallela undoubted Pulaski forms. It represents the last stage of zone III.

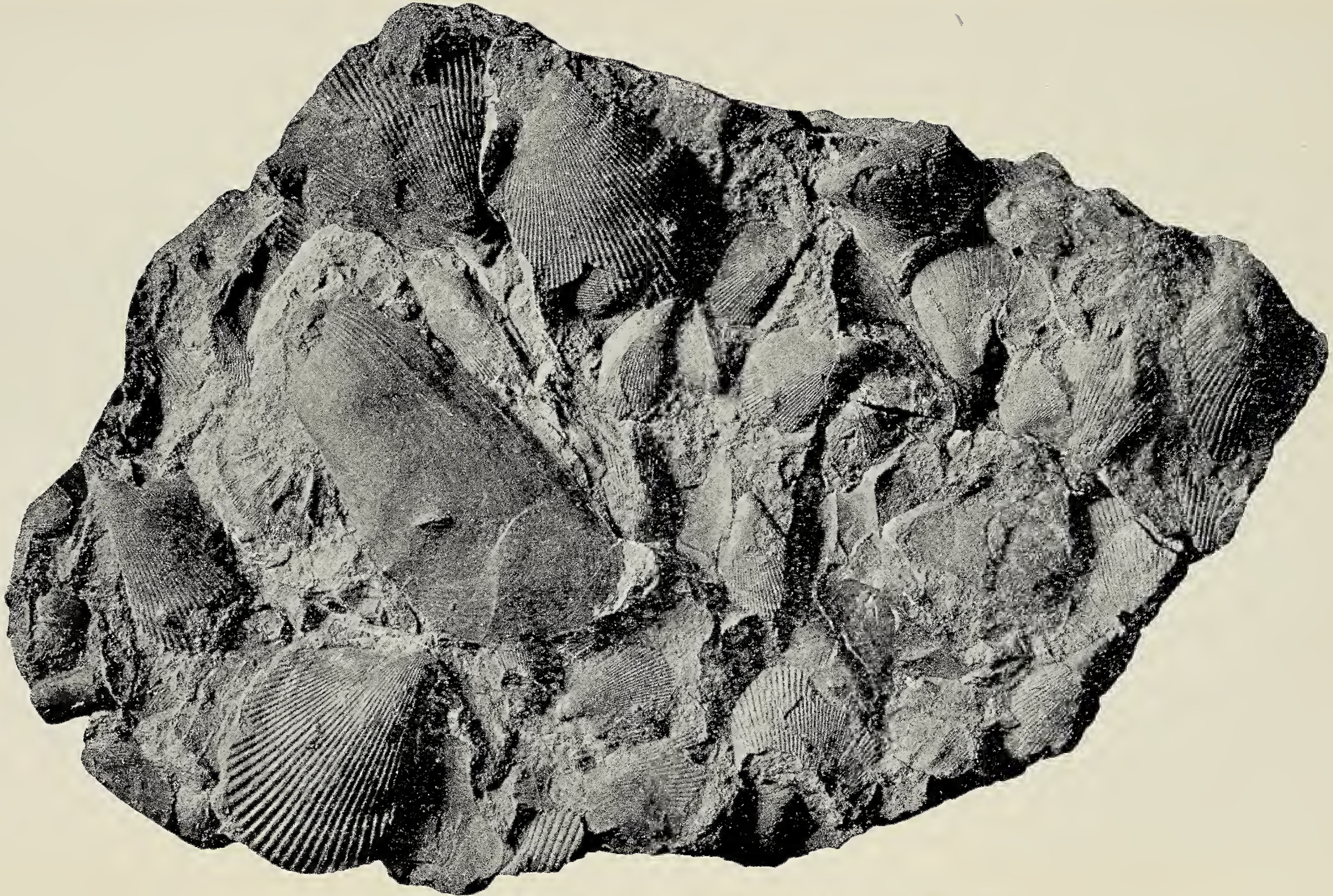
The composition of the fauna of zone III indicates that it is not fully represented in the Cincinnati section, and therefore probably represents an invasion that did not reach the Ohio basin and is there represented by the hiatus separating the Eden and Maysville and finally by the Mount Hope.

Zone IV of Pholidops subtruncata and Lyrodesma cincinnatiense. This zone contains:

'Diplograptus nexus *nov.*: Lorraine gulf *22a*
D. recurrens *nov.*: Whetstone gulf 12; Wood creek 15
Stomatopora arachnoidea (Hall): Lorraine gulf *22a*
Stigmatella irregularis Ulrich: Whetstone gulf 14; Lorraine gulf *22a*
Arthropora shafferi (Meek): Lorraine gulf 24
Bythopora arctipora (Nicholson): Lorraine gulf *22a*
Amplexopora (?) discoidea (Nicholson): Lorraine gulf 21–23, 24; Whetstone gulf 12, 14
*Escharopora pavonia Nicholson: Whetstone gulf 12, forms a thin limestone bed
Hallopora andrewsi (Nicholson): Lorraine gulf *22a*, 24
Crania *cf.* laelia Hall: Lorraine gulf *22a*
Pholidops subtruncata Hall: Lorraine gulf *22a*, 21–24; Whetstone gulf 12, 14
Trematis puncto striata Hall: Lorraine gulf *22a*
Dalmanella testudinaria (Dalman): Lorraine gulf *22a*

D. testudinaria *aff.* multisecta (Meek): Whetstone gulf 12, 13
Glyptorthis crispata (Emmons): Lorraine gulf 21*a*, 21–23
Plectambonites sericeus (Sow.): Wood creek 13
Plectambonites rugosus (Meek): Lorraine gulf 21*a*, 21–23
Rafinesquina nasuta (Conrad): Lorraine gulf 22*a*; Moose creek 13, 14
Zygospira concentrica Ulrich: Moose creek 15
Zygospira (?) erratica (Hall); Lorraine gulf 21*a*, 22*a*; Whetstone gulf 14
Pterinea (Caritodens) demissa (Hall): Whetstone gulf 14
Byssonychia radiata Hall: Lorraine gulf 21*a*, 22*a*, 24; Whetstone gulf 14; Moose creek 13–15
Modiodesma modiolare (Conrad): Lorraine gulf 21*a*, 21–23; Whetstone gulf 14
Modiolopsis sinuata Emmons: Lorraine gulf 22*a*
Whitella goniumbonata Foerste: Wood creek 13
Psiloconcha inornata Ulrich: Lorraine gulf 22*a*
P. *cf.* sinuata Ulrich: Lorraine gulf 22*a*
Cuneamya ovata *nov.*: Lorraine gulf 22*a*; Whetstone gulf 14
C. scapha brevior Foerste: Lorraine gulf 22*a*
C. neglecta (Meek): Lorraine gulf 22*a*
C. elliptica (Miller): Lorraine gulf 22*a*
Cymatonota parallela (Hall): Wood creek 13; Moose creek 13–14
Colpomya pusilla Foerste: Lorraine gulf 21*a*, 22*a*, 21–23; Whetstone gulf 12–14, Wood creek 12
Orthodesma *sp. nov.*: Whetstone gulf 14
Psilonychia *sp.*: Whetstone gulf 14
Rhytimya producta Ulrich: Whetstone gulf 14
R. compressa Ulrich: Lorraine gulf 22*a*
Clidophorus planulatus (Conrad): Lorraine gulf 21*a*, 22*a*; Whetstone gulf 12, 14; Mill creek 17; Wood creek 13
Ctenodonta pectunculoides Hall: Lorraine gulf 22*a*
C. perminuta Ulrich: Whetstone gulf 14
Lyrodesma cincinnatiense Hall: Lorraine gulf 21*a*, 22*a*, 24
Archinacella pulaskiensis Foerste: Lorraine gulf 21–23
A. subcarinata *nov.*: Lorraine gulf 22*a*
Cyrtolites ornatus Conrad: Lorraine gulf 22*a*; Whetstone gulf 14; Wood creek 13
Sinuites cancellatus (Hall): Lorraine gulf 21–23, 24; Whetstone gulf 14
Cyclora *cf.* pulcella Miller: Lorraine gulf 22*a*
C. parvula Hall: Lorraine gulf 22*a*
Liospira micula Hall: Lorraine gulf 22*a*
Hormotoma gracilis sublaxa U. & S.: Lorraine gulf 21*a*, 22*a*
Lophospira abbreviata (Hall): Lorraine gulf 21*a*
Clathrospira subconica (Hall): Lorraine gulf 24
Lophospira bowdeni (Safford): Lorraine gulf 21–23
Actinoceras *cf.* lamellosum Hall: Lorraine gulf 21–23; Whetstone gulf 14
Actinoceras crebriseptum (Hall): Lorraine gulf 22*a*
Trocholites planorbiformis (Hall): Lorraine gulf 21
Cornulites progressus *nov.*: Lorraine gulf 22*a*, 24
Isotelus *sp.*: Lorraine gulf 22*a*
Calymmene senaria meeki Foerste: Lorraine gulf 21*a*, 22*a*; Wood creek 12; Whetstone gulf 14
Odontopleura *cf.* crosota (Locke): Lorraine gulf 22*a*
Lepidocoleus jamesi (H. & W.): Lorraine gulf 22*a*
Aparchites minutissimus (Hall): Lorraine gulf 22*a*; Wood creek 13
Bythocypris cylindrica (Hall): Lorraine gulf 22*a*, 21–23; Whetstone gulf 12, 14

Plate 6



Typical fauna of Pulaski calcareous sandstone. ⅖ nat. size.

This fauna is found in the Lorraine gulf from stations 21*a*–24; in the Whetstone gulf from 12–14; in Wood creek from stations 12–15; and Moose creek 13–15.

There is no doubt that with this zone a decided change in the faunal aspect has taken place. The large fauna of upward of 60 species is clearly divided from the preceding zones by the disappearance of a number of types and still more distinctly marked off by the appearance of a great number of new forms. Characteristic types that disappear are Glyptothis crispata that was seen for the last time at station 21*a*, at the base of this zone; Modiolopsis subconcentricus which is now replaced by Modiodesma modiolare; Arthropora cleavelandi, in whose place we find, Arthropora shafferi, Aspidopora bellula which is followed by Amplexopora (?) discoidea, Pholidops cincinnatiensis, which is replaced by Pholidops subtruncata.

The important new forms are Arthropora shafferi, Amplexopora (?) discoidea, Escharopora pavonia, Stigmatella irregularis, Pholidops subtruncata, Trematis punctostriata, Rafinesquina nasuta, Zygospira concentrica, Zygospira (?) erratica, Modiodesma modiolare, Modiolopsis inornata and the new species of Whiteavesia, Psiloconcha, Cuneamya, Psilonychia, Rhytimya, among them R. producta and compressa, and Lyrodesma cincinnatiense.

The new arrivals give the fauna a distinct Maysville aspect and it is therefore a legitimate conclusion that with zone IV that stage of the Lorraine beds is reached which is distinctly Maysville in age.

The Maysville forms in zone IV are:

Arthropora shafferi (*Bellevue, Corryville*)
Stigmatella irregularis (*Bellevue*) basal
Amplexopora (?) discoidea (*Fairmount*)
Hallopora andrewsi (*Bellevue and Corryville*)
Escharopora pavonia (*Fairmount*)
Zygospira concentrica (*Fairmount*)
Byssonychia radiata (*Maysville-Richmond;* main horizon in basal Bellevue)
Pterinea (Caritodens) demissa (*Maysville-Richmond*)
Psiloconcha sinuata (*Bellevue*)
Rhytimya producta (high Fairmount or basal Bellevue)
Cyrtolites ornatus (*Maysville-Richmond*)
Calymmene meeki (*Maysville-Richmond*)

This list gives the impression that the Bellevue and Fairmount types occur in this zone in such promiscuous mixture, that it corresponds to both stages. As a matter of fact, however, the Fairmount types came principally from station 12 of the Whetstone gulf section, and station 15 of the Moose creek section, while the Bellevue forms came from Station *22a* of the Lorraine section and 14 of the Whetstone gulf section. It thus seems that there is, indeed, a differentiation possible between the Fairmount and Bellevue faunas of the Maysville; stations 12 in the Whetstone gulf and 15 of the Moose creek section representing the former and station *22a* in the Lorraine section and 14 of the Whetstone, the latter.

Alongside with these Maysville elements, there occur still a few stragglers from the Eden, such as Bythopora arctipora; then the large number of long range Ordovician fossils and finally a considerable admixture that is foreign to the Ohio basin, but characterizes the eastern development of the Maysville or the "Lorraine" element. Such are Pholidops subtruncata, Zygospira (?) erratica, Glyptorthis crispata, and the new species of Cuneamya, Orthodesma, etc. Their relations will be discussed more fully in the analysis of the geographic control of the fauna.

To this zone belong also the outcrops in Lorraine village (see p. 113).

Zone V consists of two subdivisions: Subzone V*a* of Lyrodesma poststriatum and Ischyrodonta unionoides. In this zone are found:

Bythopora dendrina (James): Lorraine gulf 25
Amplexopora (?) discoidea (Nicholson): Lorraine gulf 25
Hallopora andrewsi (Nicholson): Lorraine gulf 25-27
Pholidops subtruncata Hall: Lorraine gulf 25
Plectambonites sericeus (Sow.): Lorraine gulf 25
P. *cf.* rugosus (Meek) *var.:* Lorraine gulf 27
Zygospira modesta (Say): Lorraine gulf 25
Zygospira (?) erratica (Hall): Lorraine gulf 25
Modiodesma modiolare (Conrad): Lorraine gulf 25-27
Colpomya pusilla Foerste: Lorraine gulf 25
(?) Cuneamya scapha brevior Foerste: Lorraine gulf
Clidophorus planulatus (Conrad): Lorraine gulf 25, 26
Ischyrodonta unionoides (Meek): Lorraine gulf 25-27
Ctenodonta pectunculoides Hall: Lorraine gulf 25
Lyrodesma poststriatum Hall: Lorraine gulf 25, 27
L. *cf.* planum (*Conrad*): Lorraine gulf, 35 feet below 25
Cyrtolites ornatus *Conrad*: Lorraine gulf 25
Lophospira bowdeni (*Safford*): Lorraine gulf 25
L. bicincta (*Hall*): Lorraine gulf 25
Cornulites progressus *nov.:* Lorraine gulf 25
Actinoceras crebriseptum Hall: Lorraine gulf 25, 26
Isotelus *sp.:* Lorraine gulf 25
Calymmene meeki Foerste: Lorraine gulf 25
Lepidocoleus jamesi (H. & W.): Lorraine gulf 25

This zone differs little from the preceding, but we have separated it because here are found Ischyrodonta unionoides and Lyrodesma poststriatum, which are either absent or very rare[1] in the preceding zone as the dominant species, Lyrodesma poststriatum replacing L. cincinnatiense.

Ischyrodonta unionoides is a Bellevue form, Lyrodesma poststriatum a Maysville type of larger range. There is no evidence that this zone is younger than the Bellevue.

It is in this subzone that the typical outcrops of the Pulaski formation along the Salmon river above Pulaski village belong. The larger faunas obtained there by Ulrich, Foerste and the writer, are listed on p. 115ff and the entire fauna of the zone is given in the table in part 3.

From the Pulaski sections we may thus add to the faunal list of this zone:

Buthotrephis subnodosa Hall
Arthropora *aff.* shafferi (Meek)
Stigmatella irregularis Ulrich
Aspidopora *n. sp. aff.* spinulosa (Ulrich MSS)
Eridotrypa *n. sp. aff.* minor (Ulrich MSS)
Lingula *sp.*
Schizocrania filosa Hall
Dalmanella testudinaria (Dalman)
Rafinesquina alternata (Emmons)
R. nasuta (Conrad)
R. mucronata Foerste
Byssonychia radiata (Hall)
Modiolopsis *aff.* concentrica H. & W.
Orthodesma pulaskiense Foerste
Cymatonota pholadis (Conrad)
Pterinea (Caritodens) demissa (Conrad)
Cuneamya *cf.* elliptica Miller
Archinacella pulaskiensis Foerste
Hormotoma gracilis (Hall)
Clathrospira subconica (Hall)
Sinuites cancellatus (Hall)
Endoceras coralliferum (Hall)
Paractinoceras lamellosum (Hall)
Actinoceras crebriseptum (Hall)
Trocholites planorbiformis (Conrad)
Arthraria *sp.*
Cryptolithus lorrainensis *nov.* ("Trinucleus concentricus")
Calymmene *sp.*
Bythocypris cylindrica (Hall)
Aparchites minutissimus (Hall)
Ceratopsis oculifera (Hall)

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[1] Foerste (*op. cit.* p. 7) cites Lyrodesma poststriatum from the village of Lorraine and Ischyrodonta unionoides from a locality, 2 miles east of Lorraine (our station 17). Both of these localities represent lower horizons (see p. 17).

Cryptolithus lorrainensis occurs in such profuse number in certain beds in the lower part of the Pulaski section that this zone has been termed the Trinucleus zone by Ulrich (1913, p. 623).

Subzone V*b*, of Rafinesquina mucronata and Zygospira(?) erratica, has afforded:

Arthropora shafferi (Meek): Lorraine gulf *27b*
Bythopora dendrina (James): Lorraine gulf *27a*
Amplexopora (?) discoidea (Nicholson): Lorraine gulf *27a* (casts)
Rafinesquina nasuta (Conrad): Lorraine gulf *27b*
R. mucronata Foerste: Lorraine gulf *27a, 27b*
Zygospira modesta (Say): Lorraine gulf *27a, 27b*
Zygospira (?) erratica (Hall): Lorraine gulf *27a, 27b*
Byssonychia radiata (Hall): Lorraine gulf *27a*
Modiodesma modiolare (Conrad): Lorraine gulf *27a*
Whiteavesia nasuta (Conrad): Lorraine gulf *27a, 27b*
Lyrodesma poststriatum Hall: Lorraine gulf *27a, 27b*
Ctenodonta pectunculoides Hall: Lorraine gulf *27b*
Lophospira bowdeni (Safford): Lorraine gulf *27a*

This subzone which outcrops in stations *27a* and *27b* of the Lorraine section, is characterized by the fact that Rafinesquina mucronata and Zygospira (?) erratica fill the fossiliferous bands almost to the exclusion of other species. Both of these are eastern forms foreign to the Ohio basin. Also Whiteavesia nasuta, which here becomes common, is an eastern type. Arthropora shafferi is a Bellevue and Coryville form.

This subzone is not exposed at Pulaski.

Zone VI, of Pholadomorpha nasuta. This zone, which is represented by stations 28–32 of the Lorraine gulf section has furnished:

Arthropora shafferi (Meek): Lorraine gulf 28
Bythopora gracilis (Nicholson): Lorraine gulf 29, 30
Pholidops subtruncata Hall: Lorraine gulf 28
Rafinesquina mucronata Foerste: Lorraine gulf 29, 30
Zygospira (?) erratica (Hall): Lorraine gulf 31
Pterinea (Caritodens) demissa (Conrad): Lorraine gulf 28
Byssonychia radiata (Hall): Lorraine gulf 28, 29
Modiodesma modiolare (Conrad): Lorraine gulf 28
Whiteavesia nasuta (Conrad): Lorraine gulf 28
Pholadomorpha nasuta *nov.*: Lorraine gulf 28–30
Clidophorus planulatus (Conrad): Lorraine gulf 28
Actinoceras crebriseptum (Hall): Lorraine gulf 28

The most important fossil of this zone is Pholadomorpha nasuta which is closely related and has hitherto been identified with the Richmond form Pholadomorpha pholadiformis Hall.

In the Lorraine section the Pholadomorpha horizon does not contain any new fossils, associated with the guide fossils.

With zone VI we also unite the last fossiliferous outcrops observed in the Lorraine section, namely, stations 31 and 32. These have furnished:

Bythopora dendrina (James)
Amplexopora (?) discoidea (Nicholson)
Rafinesquina mucronata Foerste
Zygospira modesta (Say)
Zygospira (?) erratica (Hall)
Pterinea (Caritodens) demissa (Conrad)
Byssonychia radiata (Hall)
Clidophorus planulatus (Conrad)
Clathrospira subconica (Hall)
Isotelus *sp.*

In view of the long range of Pholadomorpha pholadiformis in Ontario and Quebec, it is probable that this species is also present in these uppermost beds of the Lorraine, directly below the Oswego sandstone, although we have failed to find it there. The other species are all those of the earlier beds, the large size of Caritodens demissa reached here being however noteworthy. As in the Bennett bridge section, also here the absence of Dalmanella, Plectambonites and Cryptolithus in these ultimate beds of the Lorraine is a characteristic feature, probably due to the predominant sandy facies.

To zone VI belong the Bennett Bridge exposures along Salmon river directly below and transitional to the Oswego sandstone. These have furnished to Ulrich (1913, p. 628) and Foerste (1916, p. 7) the following assemblage of forms:

Palaeophycus flexibile *nov.*
Glyptocrinus columnals
Pholidops subtruncata (Foerste, Ph. *cf.* cincinnatiensis *Ulrich*)
Rafinesquina alternata
R. mucronata
Zygospira (?) erratica
Byssonychia radiata
Modiodesma modiolare
M. *sp. aff.* milleri *et* concentrica
Pholadomorpha nasuta
Whiteavesia nasuta
Ischyrodonta unionoides
Clidophorus planulatus
Lyrodesma poststriatum
Archinacella pulaskiensis
Orthoceras *sp.* (has strong transverse striations)
Endoceras *sp.*
Isotelus *sp.*

In correlating the scattered outcrops of Lorraine rocks in the State, notably those at Pulaski and Lorraine village with the series of seven zones, that we have been able to distinguish in the Lorraine gulf or Sandy creek section, the following approximate determinations can be made.

The exposures at Lorraine village have furnished the fauna recorded on page 113. This assemblage is not exactly duplicated in any of the zones and the association of the graptolites with Pholidops subtruncata, Modiolopsis *sp.* (preconcentrica) and Glyptorthis crispata points to the basal beds of zone IV, or an early stage of the Pulaski beds. The Lyrodesma poststriatum listed by Foerste from Lorraine is probably identical with the earlier L. cincinnatiense described in this paper, and Zygospira (?) erratica has also been found by Foerste in Ontario in association with bryozoans indicating upper Eden or lower Maysville age. The absence in the Lorraine village exposures of Ischyrodonta unionoides, Modiodesma modiolare, Whiteavesia nasuta and Rafinesquina mucronata leaves no doubt that this locality is not higher than and probably in the base of zone IV of the Lorraine section. This inference is corroborated by the relative geographic position of Lorraine in regard to the beds of zone IV in the Lorraine gulf and also by the fact that the thicker sandstone beds and sandy limestone layers of the upper Lorraine disappear in Fox river below the village.

The section at Pulaski village consists of two widely separated outcrops (see p. 116), namely, that 2 miles below Pulaski and the well-known outcrops just above the village on both banks of Salmon river. The lower outcrop is characterized by the presence of Arthropora cincinnatiensis, a Mount Hope (lowest Maysville) form, in association with Modiodesma modiolare and Cymatonota parallela as belonging to the lowest Pulaski zone (III) observed.

The outcrop above or east of Pulaski has furnished a large fauna which may be considered as the typical Pulaski fauna. The fact, however, that Rafinesquina mucronata and Zygospira (?) erratica are decidedly rare fossils in this outcrop, while Ischyrodonta unionoides and Lyrodesma poststriatum are very common elements of the fauna, especially in the uppermost beds, above the bridge, would refer the Pulaski outcrops to zone V*a*.

To the fourth or fifth zone should also be referred the locality south of Dix, south of Rome, where Foerste found the faunule recorded on p. 119, while the Bennett Bridge and Salmon River falls faunas are those of our last zone.

The large collections of Lorraine fossils, in the State Museum and the United States National Museum from the Lorraine shale near Rome (Rust collection) recorded on p. 119 are obviously to be placed in the first zone. They contain such characteristic guide fossils of that zone as Pterinea rotunda, Whiteavesia *sp. nov.* Rhytimya radiata, Ctenodonta filistriata, Bollia pulchra.

Summing up, we have in the Lorraine sections here described, the following zones of the Lorraine group, excluding the Atwater Creek formation of Fulton age at the foot of the Lorraine gulf.

1 **Zone I of Cryptolithus bellulus and Bollia pulchra.** This zone is of approximate Economy age and its fauna is best exhibited along Wood creek and in the Lorraine gulf (*Wood Creek beds*).

2 **Zone II of Dalmanella emacerata and Plectambonites rugosus major.** This zone is here correlated with the Southgate member of the Eden. It is the main zone in the Lorraine gulf and is also well exposed along Moose creek (*Moose Creek beds*).

3 **Zone III of Dekayella ulrichi and Arthropora cincinnatiensis** considered as basal zone of Pulaski formation (in part equivalent to Mount Hope). Observed only at head of " gulf " just above the bridge leading to Tremaines (*Tremaines Bridge beds*) and below Pulaski.

4 **Zone IV of Pholidops subtruncata and Lyrodesma cincinnatiense.** Lower Maysville, contains two subzones (*Worthville beds*).

Subzone IV*a*. Subzone of Escharopora pavonia and Zygospira concentrica. This subzone, corresponding to the Fairmount beds of the Ohio basin is exposed in the Whetstone gulf at the gulf bridge.

Subzone IV*b*. Subzone of Stigmatella irregularis and Psiloconcha sinuata. This subzone represents the lower Bellevue beds of the western section and is well exposed along Sandy creek about Worthville.

5 **Zone V** (*Sandy Creek beds*) consists of two subdivisions.

Subzone V*a* of Lyrodesma poststriatum and Ischyrodonta unionoides. This zone is also of Bellevue age. It is exposed along the upper Sandy creek in the town of Worth.

Subzone V*b* of Rafinesquina mucronata and Zygospira(?) erratica. Also this zone is of Bellevue age. It is, like the preceding, exposed on the Upper Sandy creek.

6 **Zone VI of Pholadomorpha nasuta.** The proper correlation of this zone is still doubtful. It is exposed along the upper Sandy creek and still better at the Bennett bridge below the Salmon River falls (*Bennett Bridge beds*).

Oswego sandstone. The correlation of the Oswego sandstone has been fully discussed by Ulrich (1913, p. 627 ff.) and Foerste (1916, p. 12).

Ulrich states that excepting certain basal beds now referred to the formation, the Oswego sandstone has so far proved practically unfossiliferous, and that this is true not only for New York, but also in central Pennsylvania where the corresponding formation (Bald Eagle sandstone of Grabau) attains much greater thicknesses. In both areas, however, the rock immediately beneath contains organic remains in abundance. In Pennsylvania the underlying fossiliferous bed corresponds to the Orthorhyncula linneyi zone at the top of the lower or Fairview formation of the Maysville group, and these beds are not separated by a stratigraphic break from the Oswego (Bald Eagle) sandstone. In New York, the Oswego sandstone is stated by the same author to be situated "between the Fairview — possibly represented in New York by the Pulaski — and the Richmond (Juniata and Queenston) stage." Chiefly on account of this stratigraphic position the Oswego is correlated with the McMillan, and it is thought that its geographic situation also is such that it may very well be brought into connection by way of the Allegheny basin with the McMillan remnant of the Cincinnatian sea.

Ulrich and Foerste succeeded in tracing the fauna of the last Lorraine zone into undoubted Oswego sandstone in the cliff at Salmon river falls (Ulrich, p. 628) and thus established the fact that there is not only an entire absence of a lithologic break between the Pulaski and Oswego, but also faunal continuity.[1] Foerste (1916, p. 12) states in regard to this important point:

> The quantity of arenaceous material increases rather gradually, and this continues into the practically unfossiliferous sandstone section forming the Salmon river falls, so that there appears no lithological reason for regarding the Salmon River Falls sandstone as a distinct formation. It is merely the upper less fossiliferous part of the underlying Lorraine section. Moreover, no abrupt faunal change is noted anywhere.

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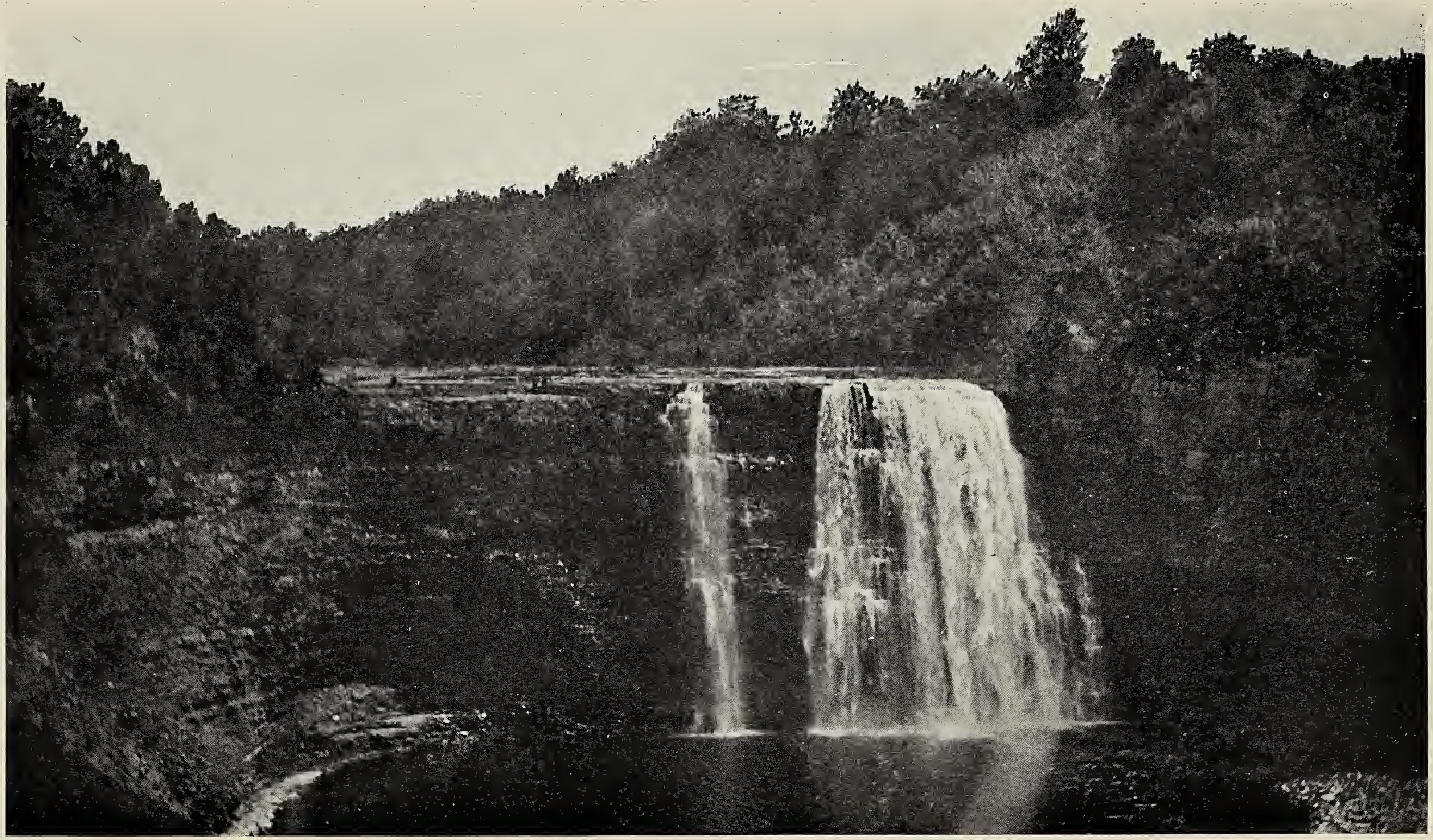
[1] Emmons (1843, p. 406) stated that Pterinea demissa and Rafinesquina nasuta occur near Rome in the lower part of the Gray (Oswego) sandstone and thus was aware of the intimate connection between the Lorraine and the Oswego sandstone that has persistently been overlooked by other New York geologists.

Plate 7



Salmon River Falls

In view of these facts, Ulrich and Foerste, at their joint visit to the Salmon River Falls section came to the conclusion that the Oswego sandstone should be considered as a closing phase of the Ordovician rather than one introductory of the Silurian. Our observations in the sections described above, corroborate this conclusion. We therefore include the Oswego sandstone among the formations of the Upper Ordovician in the stratigraphic table correlating it as Ulrich and Foerste have done with the upper Maysville, or McMillan formation.

The closer correlation and paleogeography of the Oswego sandstone has been fully discussed by Ulrich (1913, p. 628 ff.) as follows:

> Except that it passes very well for a Maysville fauna, the last [Oswego fauna at Salmon river falls] contains nothing more definitely characteristic. The other two collections, however, are much more promising, most of the species being found at Cincinnati and having a fairly restricted vertical range in the Ohio section. Judging from their position in the Cincinnati section, relying, however, chiefly on such narrowly confined species as Ischyrodonta unionoides, Whiteavesia corrugata, and Orthodesma nasutum the age of the containing beds should be the same as that of the Bellevue member of the McMillan formation, that is, oldest McMillan. Although this correlation is clearly indicated by the fossil evidence I yet hesitate to accept it as unquestionable. The doubt arises from two facts: (1) because the evidence on which the upper part of the Pulaski formation might be decided to be of the age of the Fairview is not at all satisfactory, and (2) because it appears from the work of Professor Foerste that most of the species associated on Salmon river in New York with Ischyrodonta unionoides range through thousands of feet of shaly sandstones at Three Rivers in the Province of Quebec, extending indeed to the base of the beds containing an early Richmond (Waynesville) fauna.
>
> The latter fact suggests three possibilities: First, that this well-marked fauna represents the north-middle Atlantic facies of the Maysville fauna and that it persisted in this realm with little change from the beginning of the Fairview age to the close of the McMillan age. Under this interpretation the great thickness of beds involved leads to the assumption that the Atlantic fauna had access to the late Ordovician basins in southwestern Quebec throughout the time occupied by the deposition of the Pulaski shale and the Oswego sandstone in New York, and of the two Maysville formations, with their generally very different southern faunas, in Ohio.
>
> The second possibility — deduced by the purely paleontologic method — implies that the Ischyrodonta unionoides fauna existed in both the Atlantic and Gulf of Mexico basins, and that it invaded New York and Quebec from the former, and the

Cincinnati region from the latter. It implies, further, that the narrow zone to which this fauna is confined at Cincinnati is either the full time equivalent of thicker beds in central New York and of the much greater thickness of beds in Quebec that contain the same guide fossils, or that the last represents the full depositional record of this age and the others merely later southwestwardly overlapping parts. Under this interpretation we would have to assume either of two conditions: (1) that the whole of the series in Quebec containing species of the Ischyrodonta unionoides fauna is of the age of the basal part of the McMillan of Ohio; or (2) that nearly the whole of it represents deposition in Quebec when emergent conditions prevailed at Cincinnati and hence, that by far the greater part of the series is older than the McMillan and younger than the Fairview — in other words that the hiatus between the Fairview and the McMillan in the Cincinnati section is represented in Quebec by thousands of feet of deposits. Another necessary assumption, under either of these alternative conditions, is that the major parts of the Oswego sandstone and the McMillan formation are unrepresented by deposits in Quebec.

The third possibility assumes that the Ischyrodonta unionoides fauna was confined to the Atlantic realm and that it invaded the continental basins only subsequent to the Fairview. It assumes, further, that the beds in Quebec which contain this fauna, likewise the Oswego sandstone of New York and Pennsylvania, are essentially equivalent to the McMillan plus the perhaps undeterminable stratigraphic value of the hiatus that is known to separate the McMillan from the Fairview in the Ohio valley. Under this interpretation, which seems the most probable and is adopted provisionally, the layers in the basal part of the Oswego sandstone containing the Ischyrodonta unionoides fauna must represent an early westward invasion of the Atlantic fauna that extended to Cincinnati about the beginning of the southern McMillan invasion of the Ohio valley. Subsequent to this faunal transgression the area receiving deposits of McMillan age was divided into three parts by shallowing, and perhaps emergence, of a median portion which thereafter received only sand deposits. These Oswego shallows and sand flats apparently served efficiently in separating the Atlantic fauna of the time in the Quebec province from the more varied and otherwise very different Gulf faunas whose remains we find so abundantly in the typical McMillan deposits of the Cincinnati region.

If we adopt either the first or the third of these possible correlations, the Ordovician, or at least pre-Richmond, age of the Oswego sandstone must be accepted as established. However, under the second interpretation it is still remotely possible that the middle and upper parts of the Oswego are younger than the McMillan. But this would necessitate the assumption that the fossiliferous lower part of the Oswego is separated from the overlying unfossiliferous parts by a break and hiatus corresponding to the major portion of the McMillan — an assumption that seems effectually negatived by the absence of any evidence whatever of such a break in the excellent section at Salmon River falls.

Though the Oswego is correlated with the McMillan, and probably began in New York and Pennsylvania about the same time as the McMillan in Ohio, it is not to be understood that the two formations are regarded as strictly conterminous. Such equality might be defended if the New York representative of the Oswego alone were compared with the McMillan. But the much thicker development of the former in Pennsylvania, where a maximum thickness of 700–800 feet is found, coupled with apparent local transition into the overlying Juniata, suggests that Oswego deposition may have continued into the interval between the last of the marine deposits of the McMillan at Cincinnati and the first of the succeeding Richmond invasions.

Table of Zones of Lorraine in New York

		Ohio basin	*New York*		
Cincinnatian	Maysville	Mount Auburn Corryville	Oswego ss.		
		Bellevue	Zone VI or Bennett Bridge beds Zone V or Sandy Creek beds	Upper Lorraine or Pulaski formation	Lorraine group
			Zone IV*b* or Worthville beds		
		Fairmount	Zone IV*a* or Worthville beds		
		Mt Hope	Zone III or Tremaines Bridge beds		
	Eden (Utica)	Southgate	Zone II or Moose creek beds	Lower Lorraine or Whetstone Gulf formation	
		Economy	Zone I or Wood Creek beds		
		Fulton	Atwater Creek shale		

It is seen from this table that the Lorraine group of New York contains in the three parts into which it is divisible from its faunal and lithologic aspects, the lower Lorraine shales and the Pulaski the eastern representatives of the Eden and Maysville formations of the Ohio basin, as had been recognized before; and further that the Whetstone Gulf formation is again divisible into two zones corresponding to the Economy and Southgate zones of the Eden, while the underlying Atwater Creek shale is the equivalent of the Fulton, thus completing the eastern representatives of the four subdivisions of the western Eden. In the Pulaski formation six zones could be distinguished, one of which corresponds to the Mount Hope, another to the Fairmount, while the rest would seem all to be referable to the Bellevue, which however in the Ohio basin is no more than 20 feet thick. As we shall see later, the fauna of several of these zones is so distinctly eastern in its composition, that these zones may well be considered as not represented in the Ohio basin.

We will now see which bearing the correlation here attained of the Lorraine zones with the members of the Eden and Maysville in the Ohio basin has upon the terminology of our Upper Ordovician. It is necessary to give a brief historic sketch of this terminology, as far as the Lorraine is concerned, in order to bring out the different views and their development.

CORRELATION OF LORRAINE GROUP

There has been manifested in the past years considerable disagreement as to the meaning and propriety of the various terms applied to the uppermost Ordovician rocks in this State.

The first comprehensive term used for the Ordovician rocks above the Trenton limestone was "gray sandstone and shale of Salmon river" by T. A. Conrad in the First Annual Report on the Geological Survey of the Third District of the State of New York (in the New York Geological and Mineralogical Reports for 1837, 1840, p. 166). Conrad states that the series comprising numerous alternating layers of gray sandstone and dark lead-colored friable shale is best shown in his district along the banks of the Salmon river at Pulaski, but more especially at the falls in the town of Orwell. That means that his series comprises in terms of present stratigraphic taxonomy, the Pulaski shale and the Oswego gray sandstone. The series is said to rest on the "Trenton falls series" of rocks, and to be followed by red or variegated sandstones (the Medina beds). It appears from the remarks of Conrad on the "Blue Fetid limestones and shales of Trenton falls" that he includes the Utica shale in the Trenton Falls group. On page 114, *op. cit.,* Conrad includes in the "Black limestone and shale of Trenton falls" also the "grauwacke and slates of the Hudson valley."

The conferences of the four geologists of the Survey led to a more precise definition of the geologic units, as is demonstrated by the Fourth Annual Report of the Geological Survey of the Third District, by Lardner Vanuxem (*ibid.* p. 355). Vanuxem distinguishes there the Black slate, Frankfort slate, Pulaski shales and Salmon River sandstone. Regarding the Pulaski shales it is stated, that they were called in the last report the shales of Salmon river, which name was changed to Pulaski shale, from finding them at the village of Pulaski, unaccompanied by any other mass.

Emmons, in the Report of the Second District, 1842, page 119, proposed the name Lorraine shales in place of Pulaski shale on the ground that at Pulaski only the upper part of the formation is exposed, while at Lorraine in the gorge of Sandy creek, the " entire mass " is exposed.

The Lorraine shale as defined by Emmons rests on the Utica slate and is terminated by the Gray sandstone (Salmon River sandstone). Strangely, however, Emmons did not use the rather evident general faunal and lithologic change on top of the dark to black Atwater Creek shale, at the Allendale bridge, to fix the boundary between his Utica and Lorraine, but seized upon the range of Triarthrus "becki" (eatoni) as an indication of the extension of the Utica. After describing Triarthrus eatoni as " the most constant and characteristic fossil " of the Utica, which occurs neither in the Trenton nor Lorraine, he states (*ibid.*) :

> In assigning the limits to this rock, I have been governed wholly by the presence of Triarthrus, and as this occurs associated with all the fossils of which I have given figures, I deemed it right to place them in this rock rather than in the Lorraine shales which succeed.

We see from the list of faunules published in this bulletin that Triarthrus eatoni reaches quite high up in the Lorraine. As a result of the artificial boundary we find Emmons figuring characteristic Lorraine fossils as Clidophorus scitulus ("Nuculites scitula" p. 399, fig. 2), Lyrodesma poststriatum (*ibid.* fig. 4) among the Utica fossils and making the statement that " the change in mineral from the Utica shale is gradual, the slaty or argillaceous strata are replaced slowly by those which are siliceous." If the term " Lorraine " is to be used as denoting a natural group of geologic units, the lower boundary will have to be redefined.

Emmons, not recognizing the Frankfort, made his term to include everything down to the Utica. He thus gave it the exact scope of the term "Hudson River group" at the same time adopted by Vanuxem, Hall and Mather in the final reports of their relative districts. The term "Hudson River," although widely current for a long time, was finally replaced by Emmons's term when it was found that the Hudson River shales included a great variety of formational units of very different age. The term " Lorraine " that thus became current is, according to Hartnagel (1912, p. 43), properly and with historic accuracy to be regarded as the inclusive term of which

Frankfort is the lower and Pulaski the upper unit member. It is thus used at present by the New York State Geological Survey.

Ulrich (1911, correlation table), while accepting this scope of the term "Lorraine," gave it however only local validity, that is, for North Central New York, and for purposes of general correlation divided the Eden group into the Utica and Frankfort stages.

Ulrich recognized, on our joint trip through the Lorraine gulf, the Southgate member of the Eden in a large portion of the lower Lorraine shale, and on a later excursion with Foerste, both became aware that the Lorraine section contains besides the typical Pulaski beds, which alone are exposed at Pulaski, still lower beds, which are of Eden age; while the Pulaski beds are of Maysville age. In his paper on the Ordovician-Silurian boundary, read before the International Congress (1913, p. 623) Ulrich arrived at the following conclusion:

> In north-central New York and the province of Quebec Trinucleus *cf.* concentricus is frequently found in the lower part of the Pulaski shales. This Trinucleus-zone is clearly younger than the top of the Eden at Cincinnati. Approximately 200 feet above it, that is, in the lower part of the overlying Oswego sandstone, at Lorraine and along Salmon river in New York, are beds which contain an association of pelecypods like Whiteavesia corrugata, Orthodesma nasutum, and Ischyrodonta unionoides that is found at Cincinnati only in the basal part (Bellevue member) of the McMillan formation. From this we would naturally suppose that the intervening beds correspond to the lower or Fairview formation of the Maysville group in Ohio, but the fossil evidence, though abundant, is not at all clear on this point. Besides, most of the species found in this upper horizon occur also in the upper half of the underlying Pulaski beds. Evidently some kind of barrier separated the Cincinnati or Gulf facies of the Fairview, which is recognizable in the east as far at least as Toronto, from another facies of similar, or more likely later, age that invaded from the Atlantic and established itself in central New York and on the other side of Adirondackia in southwest Quebec. As to the Pulaski Trinucleus zone itself the evidence in hand suggests two rather widely different conclusions: (1) That it falls into the hiatus commonly indicated between the top of the Eden and the base of the Maysville in the vicinity of Cincinnati, or (2) that the greater part if not the whole of the Pulaski wedges into the similarly indicated hiatus between the Fairview and McMillan divisions of the Maysville group as developed in the Ohio valley. At present the latter of these alternations appears the more probable.

This correlation finds its expression in the charts in Ulrich's "Revision," "Ordovician-Silurian Boundary," and Bassler's "Bibliographic Index" as follows:

		Cincinnati dome		*New York*	
Cincinnatian	Maysville	McMillan	Mount Auburn Corryville Bellevue	Oswego sandstone	Lorraine
		Fairview	Fairmount Mount Hope	Pulaski shale	
	Eden	Frankfort	McMicken Southgate Economy	Frankfort shale and Indian Ladder shale	
		Utica	Fulton	Utica shale	

Approximately the same scope is given the Lorraine by Schuchert (1910, p. 530 ff.) who correlates the three zones of the Eden and the two lowest zones of the Maysvillian (Mount Hope and Fairmount zones) in part with the Lorraine of New York. In the final chart of his work, however, he distinguishes the Utica, Eden and Lorraine ages, and also in his Textbook of Geology (1915, p. 635) he distinguishes on plate 8 between the Utica-Eden invasion on one hand, and the Maysville-Lorraine on the other. Schuchert thus inclines to restrict the term " Lorraine " to the upper or Maysville correlative of the group, which is approximately the Pulaski and overlying rocks.

Finally, Foerste, who has visited the New York section of the Lorraine to gather the information necessary for a correlation of the Upper Ordovician of the provinces of Ontario and Quebec in Canada with that of the United States, arrived at the following preliminary conclusions (1914, p. 250) :

> One of the results of the investigations at the Bennett bridge locality was the discovery of very typical specimens of Whiteavesia pholadiformis, associated with Ischyrodonta unionoides, and other forms which Dr E. O. Ulrich regarded as suggesting middle Maysville (lower Bellevue) affinities. Moreover, at the distinctly lower horizons exposed along the river east of Pulaski, the same Ischyrodonta unionoides occurred associated with various other forms which to Doctor Ulrich again suggested middle Maysville rather than Richmond affinities. This is not strange in view of the fact that this fauna at Pulaski contains Trinucleus. It is not intended by these observations to convey the impression that the middle Maysville age of the Pulaski and Bennett Bridge faunas has been definitely determined, but rather that the Bennett Bridge fauna, with its Whiteavesia pholadiformis, did not present other forms regarded as characteristic of the Richmond while forms suggesting middle Maysville age were present there and at Pulaski.

For the present probably it would be safe to assume that the upper or Lorraine fauna is younger than the Eden at Cincinnati and older than the upper or McMillan division of the Maysville, while the lower, shaly part of the Lorraine, below the typical Pulaski zone, may be correlated with the Eden. In the absence of fossils, the typical Salmon River Falls or Oswego sandstone may be correlated with the upper Maysville.

In his latest publication, Foerste (1916, p. 6, 13) considers it unfortunate that Conrad's term "Salmon River" was ignored and that both the terms Hudson River and Lorraine gained such wide currency. He believes, however, that since as a matter of fact the term "Lorraine" has grown into general use, both in the United States and Canada, it should be retained, and proposes to apply it to the entire series of rocks exposed in the Lorraine gulf and along the creek above the gorge inclusive of the "Oswego sandstone," which he replaces for reasons of priority by the term "Salmon River."

Foerste, recognizing the fact that no evidence of the presence of the typical Frankfort shales, as described by the writer from the Mohawk valley, has been secured so far in the Lorraine gulf, considers the correlation of any part of the shales in the Lorraine gulf section with the Frankfort as inadvisable. This would leave the Eden part of the Lorraine section without a name, and since my work had shown a close faunal relationship between the Frankfort and Utica, Foerste would propose the following classification for the New York rocks here under consideration (see 1916, p. 13):

Medina	
Lorraine	Salmon River sandstone
	Pulaski shales and sandstones
	Lower Lorraine shales, unnamed (near Eden of Cincinnati)
Unnamed group	Frankfort
	Utica

Summing up, we have found that two classifications have been proposed. The first would divide the Lorraine group into the Pulaski and Frankfort formations. It was originally proposed by the first Survey of New York and is used by the New York Survey to this day. It is also adopted by Ulrich. It is based on the view that the Frankfort shale and the lower Lorraine shales of the Lorraine section are practically equivalent and correspond to the upper three members of the Eden, (Economy, Southgate, McMicken).

The second, proposed by Foerste, would separate the lower Lorraine and Frankfort and unite the latter with the Utica in a separate group.

We have here brought forward evidence to show that the Frankfort, while clearly containing for the most part a depauperated Utica fauna, also has elements of its own (see p. 59) and others that connect it with the Eden, and more especially with the Fulton and Economy; and that further it merges northward into lower Lorraine shales, and underlies there the Economy beds, while the northernmost Frankfort " facies " affords Fulton fossils. At the same time, the Indian Ladder beds in the lower Mohawk valley contain a good Southgate fauna. The Frankfort is thus apparently but a local facies of the earliest Eden, formed in a fairly inclosed basin or embayment in which the Utica fauna was able to linger a little longer than elsewhere.

While the Frankfort is thus, on one hand, closely connected with the Utica faunistically and lithologically, by slow vertical gradation, it is equally closely connected with the basal members of the lower Lorraine by horizontal gradation, and synchronism.

We infer from these facts:

1 The term " Frankfort " could not very well be applied to the whole of the lower Lorraine shales.

2 Therefore the lower Lorraine shales should receive a separate name (Whetstone Gulf shale).

3 The Frankfort being of the same age as the lower portion of the lower Lorraine shale and merging into it, could be incorporated into the Lorraine, as the New York Survey has done from its beginning, but not as its characteristic development but only as

4 A local shore facies of the lower Whetstone gulf horizons.

5 The Utica shale, although connected with the Frankfort-Whetstone gulf series by lithologic and faunistic gradation, represents a different stratigraphic unit, that is

a Older than the Eden of the Ohio basin where it is represented only by its last or Fulton phase, if the latter is not already as young as the Frankfort-Atwater Creek shale, as is suggested by certain fossils common to both; and

b Represents a different marine invasion, from another (southeast) direction than the later (southwest) Eden invasion.

It therefore is properly separated from the Eden as an independent division of the Cincinnatian, being in our opinion the basal unit of the Cincinnatian and largely represented in the Ohio basin by the hiatus between the Mohawkian and Cincinnatian.

6 The Deer River and Atwater Creek shales are post-Utica in age, the former lithologically of the character of the Utica, the latter of that of the Utica-Frankfort transition beds. The Deer River is probably a late member of the Gloucester, the Atwater Creek shale the northern thin continuation of the early Frankfort shale. Since both the Atwater Creek shale and the Frankfort contain Fulton elements, and the Fulton shale itself, as shown by the fossil lists of Ulrich (1880) and Bassler (1916), is more closely connected with the succeeding Eden than with the Utica of New York, we see no objection in drawing the line between the Utica-Frankfort in central New York, between the Deer River and Atwater Creek shale in the Black river valley, and finally in keeping the Fulton in the Eden as the initial stage.

For the lower Lorraine shales we have selected the name "Whetstone Gulf beds" from the fine exposure of the lower Lorraine shales in the picturesque Whetstone gulf near Martinsburgh in Lewis county, N. Y. Here also the contact with both the underlying Atwater Creek and overlying Pulaski beds is shown.

Accepting further the views of Ulrich and Foerste that the Oswego sandstone properly belongs with the Cincinnatian, we get the following table of the Cincinnatian of New York.

Table of Cincinnatian of New York

			Ohio	*Central New York (Utica)*		*North-central New York (Watertown)*	
Cincinnatian	Maysville	McMillan	Mount Auburn				
			Corryville	Oswego		Oswego	
			Bellevue				
		Fairmount	Fairmount	Pulaski	Lorraine	Pulaski	Lorraine
			Mount Hope				
	Eden		Mc Micken Southgate	Whetstone Gulf		Whetstone Gulf	
			Economy Fulton	Frankfort		Atwater Creek Deer River	
				Utica		Cobourg	
			Trenton	Trenton		Trenton	

PALEOGEOGRAPHY OF THE LORRAINE GROUP

Faunal Evidence

Whetstone Gulf formation. In attempting to elucidate the paleogeography of our Lorraine, we have to consider the evidence from the faunas and their correlations with those of other regions; further, that from the lithology of the rocks, and finally, that from the general cycle of formations traceable around the Adirondacks. All of these combine to give us a picture of the marine conditions and connections in Lorraine time.

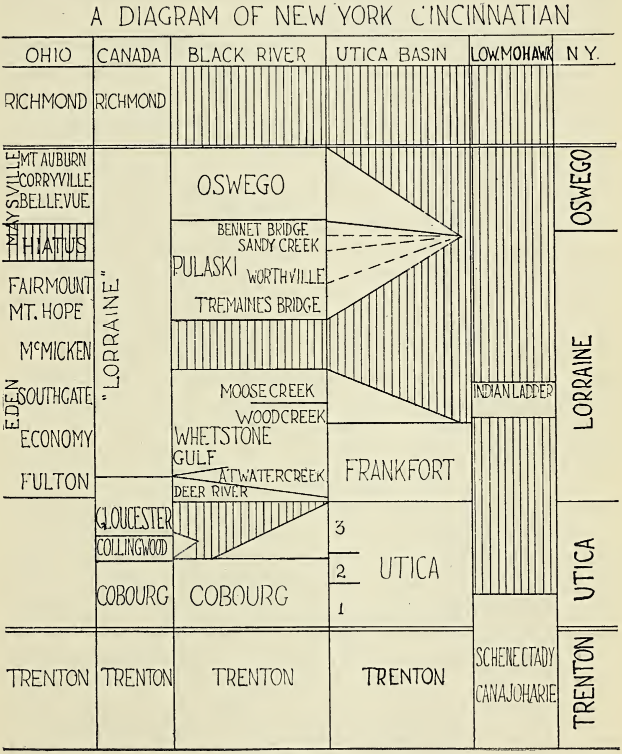


Figure 7

We will first consider the faunal relations which throw light on the extension of the Lorraine sea into the adjoining regions.

In considering the correlation and distribution of the Lorraine faunas, it is necessary to deal separately with those of the Whetstone Gulf and Pulaski beds, since their differences are so great as to indicate faunal invasions from different quarters.

The two zones of the Whetstone Gulf beds can be correlated fairly accurately with the Economy and Southgate members of the Eden of the Ohio valley. Including the Atwater Creek shale, which corresponds to the Fulton member, we have then in north central New York all the units of the Eden formation or group of Ohio, save the last or McMicken member.

In the first zone, the fauna is overwhelmingly one of Economy and Eden fossils of the Ohio basin in general; and there can be no doubt that the connection with the Cincinnati region was direct. There are a few local elements such as one might expect in a region 500 miles distant from the Cincinnati dome, whence the Eden fauna has become so fully known that it now furnishes the standard for the group. Such forms characteristic of the eastern development of the Economy fauna are the new species and varieties cited in the list on p. 124, among them several species of local importance only, and probably also the few surviving Utica forms, notably Leptobolus insignis, most of the graptolites and Triarthrus eatoni. The latter continues also through the next (Southgate) member. According to Ulrich (1911, p. 296), T. eatoni, while extremely common in the Fulton beds, is absent in the abundantly fossiliferous Economy beds, but reappears in the Southgate beds. In Quebec where Foerste (1916, p. 55), in the St Hyacinthe section traced it into the zone with Catazyga erratica, it lived still longer. This trilobite seems thus to have advanced west several times from his eastern or Atlantic home.

Still more suggestive is the occurrence of Diplograptus nexus at the top of the Atwater creek shale and the two following lower Lorraine zones. This characteristic graptolite which is barely distinguishable from the Richmond species, D. peosta, with which the writer has formerly united it, belongs to the group of Orthograptus truncatus Lapworth and is similar to the last variety socialis of the same. O. truncatus appears first in Great Britain in the zone with Pleurograptus linearis, or in beds of Utica age. In New York this type makes its first appearance in the uppermost Atwater Creek shale

(Fulton), and in the later Eden it has spread to Ontario West. In the Richmond it is known as D. peosta from Iowa, Minnesota and Wisconsin and is thus associated with Arctic or North Atlantic faunas. It is thus very probable that in D. nexus we have another Atlantic immigrant into the eastern Eden basin. It is interesting to note that in the uppermost Ordovician this type of graptolite has reached the Pacific basin and is found in Peru (Newton).

The second zone of the Whetstone Gulf beds contains a rather large fauna, seventy-two species being cited here as the result of by no means exhaustive collecting. This fauna consists, as we have already pointed out, of a sufficient number of Southgate guide fossils to conclusively fix its taxonomic position. But it also contains, besides the stragglers from the preceding zone and the considerable number of long range forms, a certain admixture of new species, mostly lamellibranchs — some of them, as Whiteavesia subplana quite common, and above all certain types which from their uniform distribution in the Ohio basin and in the Pulaski beds we should not expect until Maysville-Pulaski age is reached. Such are the Maysville forms: Glyptorthis crispata, Cymatonota pholadis, Clidophorus planulatus, Archinacella pulaskiensis, Lophospira abbreviata and Cyrtolites ornatus. All of the latter find their principal development either in the Maysville or in the Pulaski beds. Some of them are clearly local or eastern forms. Thus, Glyptorthis crispata has been found only in New York; and Cymatonota parallela and Lophospira abbreviata, as well as the new species are not known from the western Eden and, therefore, are to be considered as characteristic of the eastern province.

Likewise a large number of typical Southgate forms are entirely missing in our zone II. Foerste (1916, p. 85, 94), who found Eden faunas mainly corresponding to the middle Eden (upper Economy and Southgate) in various localities of western Ontario, and also recognized an Eden fauna in the lower Lorraine of Quebec, has concluded that the Eden fauna is so sparingly represented in the Canadian strata that it must have been a southern invasion there from the Ohio region.

This conclusion fully agrees with the charts of the Eden sea published by Ulrich (1914, p. 662) and Schuchert (1915, p. 635), This sea reached New York in Economy time, but attained its

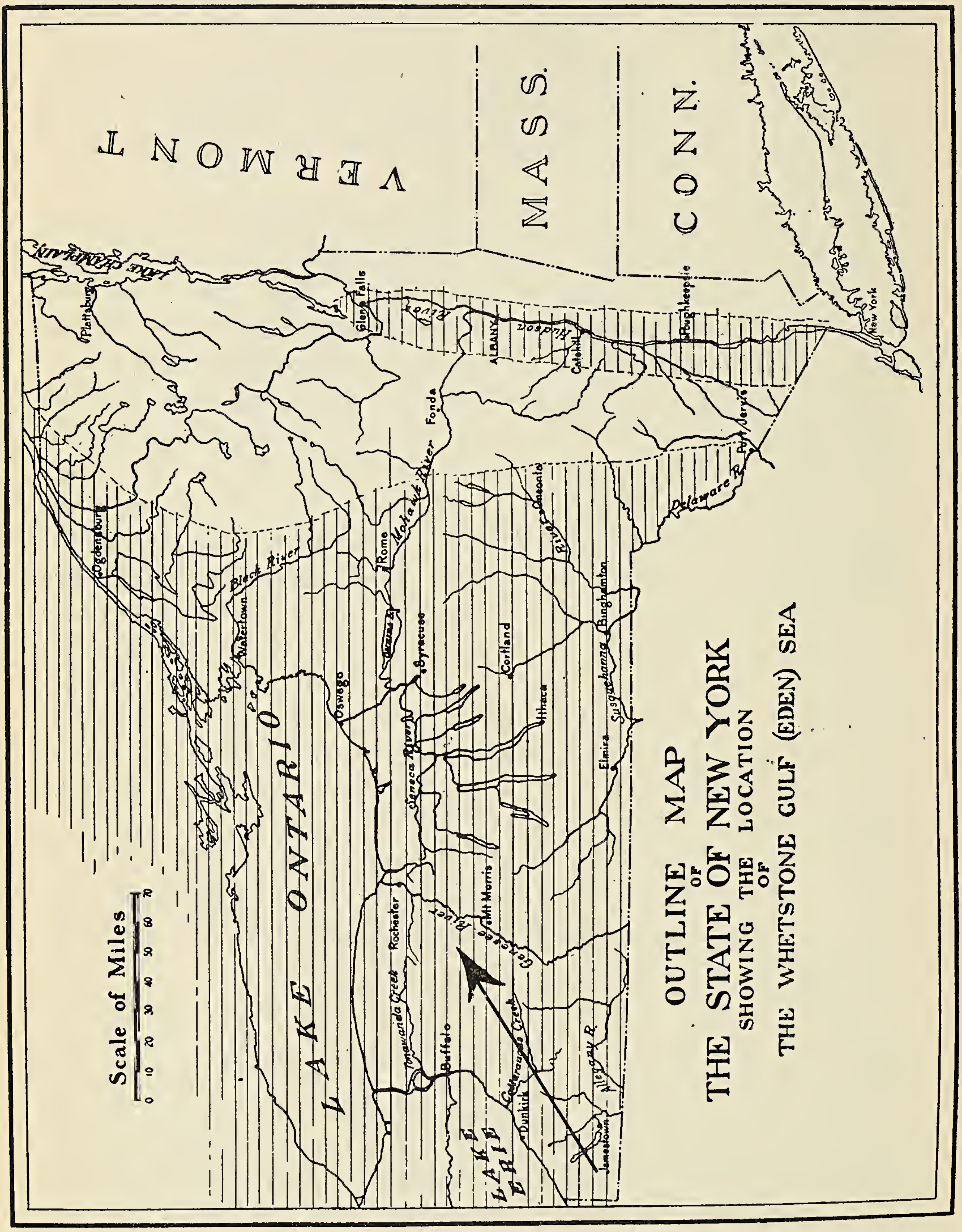

VERMONT
MASS.
CONN.
LAKE CHAMPLAIN
Plattsburg
Glens Falls
Hudson River
ALBANY
Catskill
Poughkeepsie
New York
Port Jervis
Delaware R.
Oneonta
Fonda
Mohawk River
Rome
Ogdensburg
Black River
Watertown
LAKE ONTARIO
Oswego
Oneida L.
Syracuse
Cortland
Ithaca
Binghamton
Susquehanna
Elmira
Seneca River
Mt Morris
Genesee River
Rochester
Tonawanda Creek
Buffalo
Cattaraugus Creek
Dunkirk
LAKE ERIE
Allegany R.
Jamestown
Scale of Miles
0
10
20
30
40
50
60
70
OUTLINE MAP
OF
THE STATE OF NEW YORK
SHOWING THE LOCATION
OF
THE WHETSTONE GULF (EDEN) SEA

Figure 8

farthest extension north in Southgate time, when it spread east of the Lake Huron region into Ontario and northeast into Quebec, and sent a separate arm into eastern New York (Indian Ladder beds).

In McMicken time it apparently withdrew from these northern areas.

The notable differences between the New York, Cincinnati and Canadian faunas of Southgate time, suggest that even at the time of the farthest northern extension of this sea, there were still left many, more or less basin-like provincial areas in the shallow epicontinental sea. This fact is most clearly brought out in this State by the difference between the middle Whetstone Gulf and the Indian Ladder faunas, which are both of Southgate age.

The Indian Ladder beds (Ruedemann, 1912, p. 51) have afforded:

Dictyonema arbusculum Ulrich
Diplograptus (Orthograptus) nexus *nov.*
Dicranograptus nicholsoni Hopkinson
Columns and calyx plates of a cystid allied to Cheirocrinus
Heterocrinus columnals
Hallopora onealli (James)
Arthrostylus tenuis Ulrich
Helopora *sp. nov.*
Rhinidictya *cf.* parallela (James)
Rafinesquina ulrichi (James)
Plectambonites centricarinatus Ruedemann
P. plicatellus (Ulrich)
Dalmanella multisecta (Meek)
Cornulites *cf.* flexuosus Hall
Hyolithes *sp.*
Lepidocoleus jamesi (Hall and Whitfield)
Ceratopsis chambersi (Miller)
Cryptolithus bellulus (Ulrich)
Odontopleura crosota Locke
Calymmene *sp.*
Dalmanites (Pterygometopus) *sp.*

By a comparison of this list with that of zone II on p. 125, it will be found that the two have only a few species (Diplograptus nexus, Hallopora onealli, Dalmanella multisecta, Cryptolithus bellulus, Odontopleura crosota and Calymmene) in common and differ in the other two-thirds of the faunules, which moreover comprise the dominant forms. It is possible that the Indian Ladder subhorizon is also present in the sections of northern New York and has not yet been discovered, but it is more probable that the faunule represents an independent advance of the Eden sea northward in one of the long troughs developing in the Appalachian region. The distribution of the Indian Ladder beds in a narrow, north-south extending belt, fully agrees with this inference.

Between the Indian Ladder embayment near Albany and the first appearance of the Whetstone Gulf formation near Rome, the Ordovician series is closed by the Frankfort shale. If the latter also extends into Southgate time as suggested by Doctor Ulrich, then we have here still a third development of Southgate beds in this State, containing but an impoverished Utica fauna, although reaching a considerable thickness and representing another embayment more or less separated from the open Eden sea.[1]

Diagram to show Relations of Cincinnatian of New York to that of Ohio.

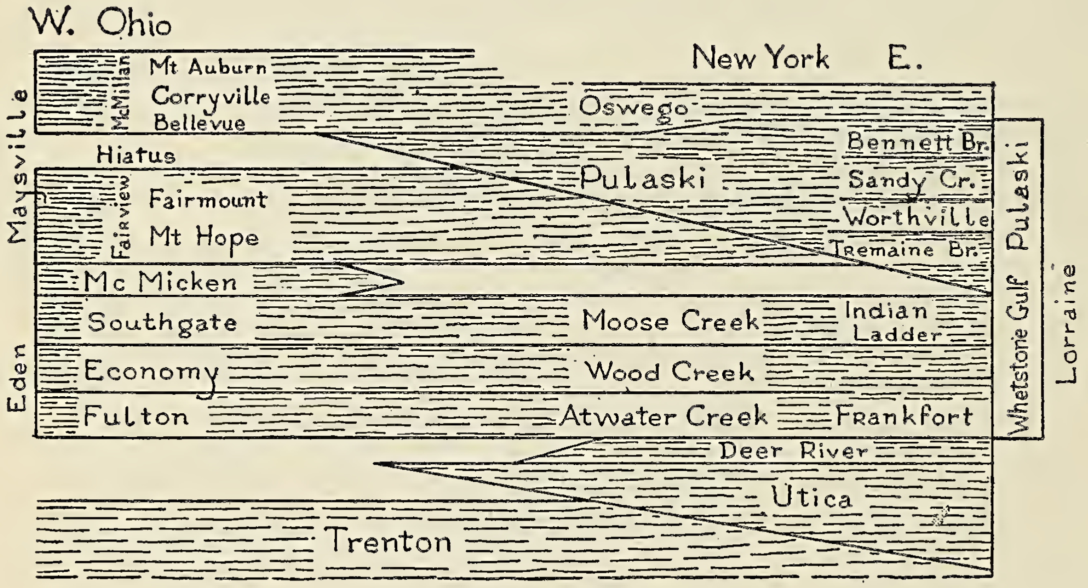


Figure 9

The Frankfort is, in the Mohawk valley, overlain by the Oneida conglomerate, but north of Rome it is followed by the Whetstone Gulf formation which there attains such thickness that it must have extended a considerable distance eastward beyond the present outcrops and over the southern slope of the Adirondacks. It is then to be inferred that all these rocks were eroded again before the inception of the Silurian era and that the Eden sea extended considerably east beyond the present distribution of the Whetsone Gulf beds.

Pulaski formation. In the Pulaski formation the first three of the five stages into which the Maysville is divided in the Cin-

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[1] At Cincinnati different zones of the Southgate contain large and almost entirely different associations of fossils. The make-up of the faunal invasions thus varied greatly from time to time. Less than a fourth of the whole Southgate fauna goes all through, the others are confined to narrow zones. Similar distribution of species prevails through all the Cincinnatian (E. O. Ulrich).

cinnati region, could be recognized, by the Mount Hope, Fairmount and Bellevue stages; and the Corryville and Mount Auburn stages are possibly represented by the barren Oswego sandstone. Of these the Mount Hope stage is based on the outcrop below Pulaski village with Arthropora cincinnatiensis. It has furnished but a small faunule, largely of long range noncommittal forms.

The outcrop with Arthropora cincinnatiensis represents, however, but the upper portion of zone III. With that zone the Pulaski formation is introduced in the Lorraine section. As we have shown before, it can not be directly correlated with any of the Cincinnati zones. It holds, in the Lorraine section, the place corresponding to the last Eden zone, the McMicken, and also contains such fossils as Dekayella ulrichi that are quite characteristic of the McMicken. On the other hand there appear such a number of Pulaski or Maysville forms, as Escharopora pavonia, Modiodesma modiolare, Ischyrodonta unionoides, etc., that the zone has to be considered as rather the beginning of the Pulaski (Maysville) than the end of the Whetstone Gulf formation or of the Eden portion of the section.

The composition of the fauna of zone III indicates that it is not fully represented in the Cincinnati section, and therefore probably represents an invasion that did not reach the Ohio basin and is there represented by the hiatus separating the Eden and Maysville, and finally by the Mount Hope.

This invasion must have come from the east, either the northeast or Quebec region; or the southeast or Appalachian region. The northeast or Quebec region seems to be excluded by the results of Foerste's investigations, who (1916, p. 67) expressly points to the absence of some of the characteristic Pulaski forms cited from zone III, as Modiodesma modiolare, Ischyrodonta unionoides and Glyptorthis crispata as being absent from the Quebec section and thereby indicating the continued functioning of the Frontenac axis in Lorraine time. On the other hand, the Appalachian region as the probable path of this invasion is clearly suggested by Bassler's recent investigations in Maryland (Bassler 1919, p. 178), whence he records such characteristic Pulaski forms as Zygospira (?) erratica, Modiodesma modiolare, Ischyrodonta unionoides, Whiteavesia nasuta and Orthoceras lamellosum.

The Fairmount zone is recognized in zone V*a*, below the gulf bridge of Whetstone gulf and also on Moose creek. Alongside of such Fairmount elements as Amplexopora (?) discoidea, Escharopora pavonia, Zygospira concentrica and Rhytimya producta, occur eastern forms, but not in sufficient strength to give the faunule a decidedly different aspect from that of the more western exposures.

It is different with the basal Bellevue stage, represented in zone IV*b*, and exposed in stations *22a* at Worthville and station 14 in the Whetstone gulf, and Wood creek station 13. Here besides the Bellevue types Arthropora shafferi, Stigmatella irregularis (basal Bellevue), Dalmanella fairmountensis and Psiloconcha sinuata and P. subovalis[1] and the large number of long range types, an astonishingly large biota of new forms is found, mainly lamellibranchs, that are not known, or at least not yet recorded, from the Ohio basin, namely, Pholidops subtruncata, Zygospira (?) erratica, Modiolopsis sinuata, Whitella goniumbonata, Psiloconcha sinuata borealis, Cuneamya ovata, C. neglecta pristina, Orthodesma *sp. nov.*, Psilonychia *sp. nov.*, Archinacella pulaskiensis, A. subsulcata, Lophospira abbreviata, Actinoceras crebriseptum, Trocholites planorbiformis, Cornulites progressus. Of these the new species of Modiolopsis, Whitella, Cuneamya, Orthodesma and Psilonychia, as well as Archinacella subcarinata, Lophospira abbreviata and Actinoceras crebriseptum have been recorded from neither the well-searched Ohio basin, nor from the Quebec region and are therefore in all probability, southeastern immigrants. These give the fauna a strongly independent or localized aspect. Besides these a certain number, and among them the most characteristic elements of the fauna, are such that occur only in the New York Lorraine and in the Quebec region. These point clearly to a northeastern marine connection or derivation of an important part of the fauna of zone IV. Such species are Pholidops subtruncata, Zygospira (?) erratica,

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[1] Except A. shafferi, the forms mentioned as Bellevue forms occur in Ohio in a locally developed thin shale at the very base of the Bellevue. Its fauna is predominantly one of pelecypods. This bed expands to the north from Cincinnati and apparently attained much greater development in New York (E. O. Ulrich).

Psiloconcha sinuata borealis, and Archinacella pulaskiensis. The occurrence of Psiloconcha sinuata, the Ohio form, as well as of P. sinuata borealis, the Quebec form is interesting in corresponding to the intermediate position between the two respective regions. Pholidops subtruncata occurs according to Foerste, besides in the Quebec region, also at numerous localities in "Ontario east," or east of the Frontenac axis. It is thus suggestive of binding the adjoining New York, Ontario east and Quebec regions into one geographic province of middle Maysville age.

Zygospira (?) erratica, which is one of the important guide fossils of the Pulaski formation in New York is also well established in the Lorraine of the Quebec region, but absent in the Ohio basin, thus announcing itself as an eastern immigrant. It is, therefore, quite interesting to note that according to Foerste's studies (1916, p. 70, 71, 78) this species has spread northwest into the Toronto region and even as far as Meaford, on Georgia bay. In the Toronto region it is associated with such typical Pulaski forms as Whiteavesia nasuta, and Ischyrodonta unionoides, suggestive of the temporary advance of the Pulaski fauna in that direction. Apparently, therefore, Zygospira (?) erratica reached the northwest not until after zone IV*b* was deposited and also in New York it is still a rare fossil in zone V*b*, in distinction from the common Pholidops subtruncata.[1]

The next zone, V, consists of two subdivisions. V*a* is characterized by the abundance of Lyrodesma poststriatum, that now replaces L. cincinnatiense and of Ischyrodonta unionoides, that was rare before, though present. The index-fossils of this zone are well known from the Ohio basin, Ischyrodonta unionoides being a Bellevue form and Lyrodesma poststriatum a Maysville species of longer range. Altogether the Ohio Maysville forms seem to prevail again and the admixture of typical New York-Quebec types, is very small, consisting of Zygospira (?) erratica, Ctenodonta pectunculoides and Paractinoceras crebriseptum. Foerste has not recorded Ischyrodonota unionoides from Quebec, while Lyrodes-

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[1] Meanwhile Z. (?) erratica has also been recorded by Bassler (1919, p. 275) from the Fairview division of the Martinsburg shale in Pennsylvania. This is an important clue to the continuation of the southeast marine connection of the Lorraine sea, noted under zone III.

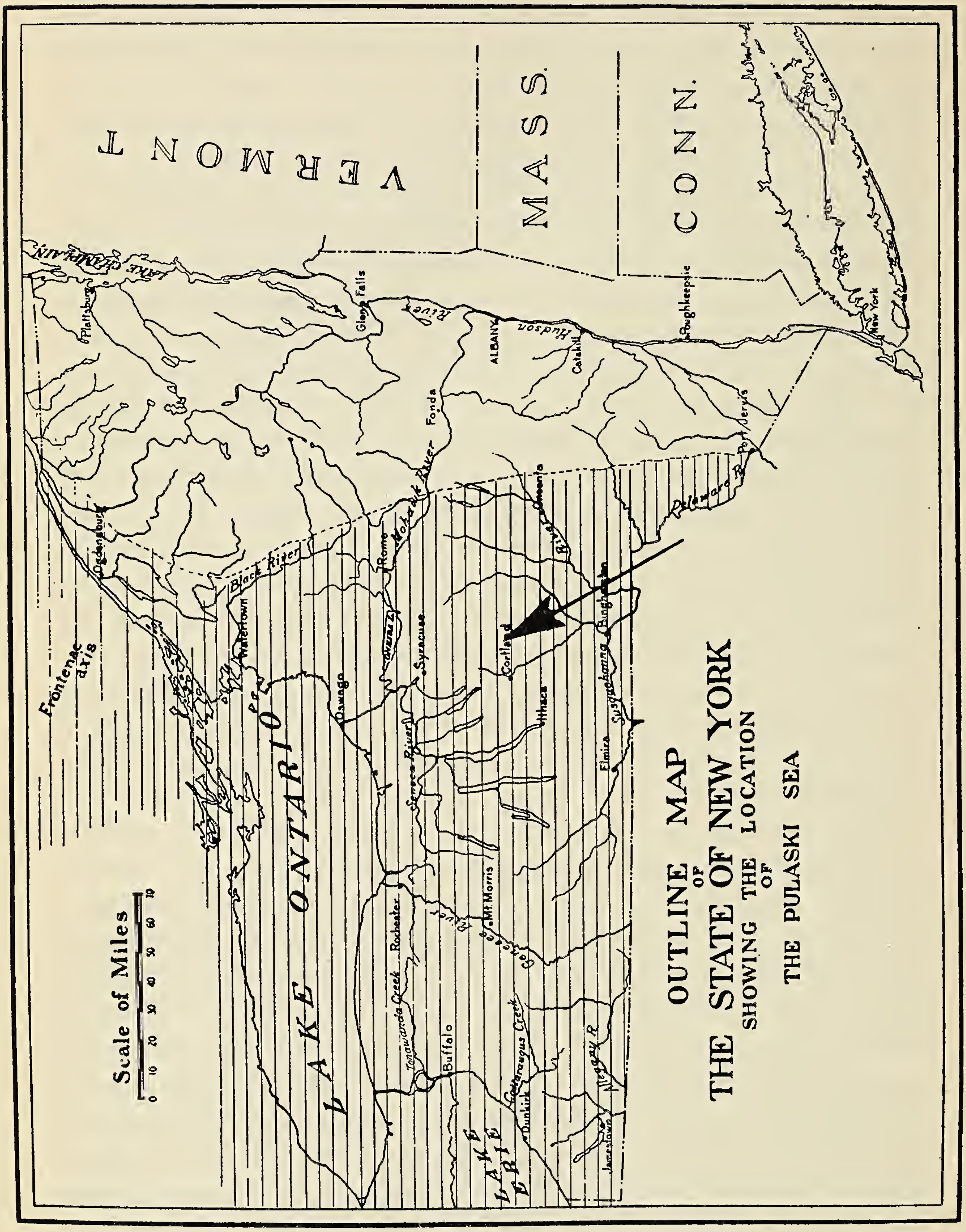
OUTLINE MAP OF THE STATE OF NEW YORK SHOWING THE LOCATION OF THE PULASKI SEA
Scale of Miles
0 10 20 30 40 50 60 70
VERMONT
MASS.
CONN.
LAKE CHAMPLAIN
LAKE ONTARIO
LAKE ERIE
Frontenac axis
Plattsburg
Ogdensburg
Watertown
Black River
Glens Falls
River
Hudson
ALBANY
Catskill
Poughkeepsie
New York
Port Jervis
Delaware R.
Fonda
Mohawk River
Rome
Oswego
Syracuse
Owasco L.
Seneca River
Cortland
Ithaca
Oneonta
River
Binghamton
Susquehanna
Elmira
Rochester
Mt Morris
Genesee River
Tonawanda Creek
Buffalo
Cattaraugus Creek
Dunkirk
Allegany R.
Jamestown

Figure 10

ma poststriatum occurs in Quebec as well as in Ontario east and west. The preponderance of forms points therefore apparently towards the southwest.

In subzone V*b* Rafinesquina mucronata and Zygospira (?) erratica are the dominant species. Both are absent in the Ohio basin, although R. mucronata, is closely allied to R. squamula (see Foerste, 1914, p. 265). R. mucronata a very well-marked species is widely spread and has a considerable range in Quebec and Ontario east, and in a few instances has also reached Ontario west (See next zone). The two are associated with a small assemblage of widely distributed forms and indicate a northeastern incursion in Bellevue time, not represented in the Ohio basin.

In the last zone, that of Pholadomorpha nasuta the faunule has again, in Pholidops subtruncata, Rafinesquina mucronata, Zygospira (?) erratica, Whiteavesia nasuta, Paractinoceras crebriseptum, a strong northeastern element, connecting it with the Quebec region and Ontario east. It is apparently this zone which for a brief interval, extended northwest, where it appears in the exposures along the Humber river at Weston, 3 miles northwest of Toronto, and is represented (see Foerste, 1916, p. 74) by the following typical upper Lorraine faunule:

Plectambonites sericeus
Rafinesquina alternata (flat form)
R. mucronata
Modiolopsis concentrica
Pholadomorpha pholadiformis
Colpomya faba
Cymatonota lenior
Ischyrodonta curta (-unionoides)
Lyrodesma poststriatum
Cyrtolites ornatus
Catazya erratica
Pterinea demissa
Byssonychia radiata borealis
Clathrospira subconica
Cyclonema bilix
Loxoceras
Endoceras *sp.*
Calymmene *sp.*
Arthraria *sp.*

While the Pulaski sea of New York was clearly intermittently connected with the Quebec region, as set forth above, and for a briefer interval also extended northwestward into Ontario, it had, probably a still more important connection with the southeast, the Allegheny basin, as is clearly brought out by the recent investigations of Bassler. Bassler (1919, p. 178 ff.) cites from the Maysville division of the Martinsburg shale in Pennsylvania not only Zygospira (?) erratica, as mentioned before but also such characteristic lamellibranchs of the last two Pulaski zones as Clidophorus planulatus, Ischyrodonta unionoides, Byssonychia radiata, B. praecursa (common in Pulaski drift of New York), Pterinea (Caritodens) demissa, Modiodesma modiolare and Whiteavesia nasuta. Likewise the cephalopod Orthoceras lamellosum. This fact, as well as the continuation of the superjacent and intimately connected Oswego sandstone from New York to Pennsylvania, indicates a sea in late Lorraine time that was open towards southeast, and most probably had advanced from that direction.

For a short time the Pulaski sea that advanced into Ontario appears also to have reached the Ohio basin. This Pulaski wedge is found in a bed at the top of the Fairmount that contains such Pulaski forms as Orthodesma nasutum and Isotelus maximus pulaskiensis.

In surveying the relations of the Lorraine of New York with the Ohio basin on one hand and the Quebec-Ontario and Pennsylvania-Maryland regions on the other, it appears that in the Whetstone Gulf-Eden time these were more distinctly with the west, or in other words, that the Frontenac axis was then operative as a barrier of some sort between the New York Lorraine sea and the northeastern embayment of the Atlantic (see Ulrich's chart); while with the beginning of the Maysville-Pulaski period the interrelations between the New York sea and that of the Quebec region became so close that direct communication must be assumed for a large part of the time; and likewise there was connection between the Lorraine sea and the Atlantic by means of the Pennsylvania-Maryland, (Allegheny) basin. These relations are well shown in the chart of the Maysville sea of the Fairview age by Ulrich (1913, p. 663). It will be seen from this map that the Quebec region is only considered an embayment of the Pulaski sea. It is probable from the facts brought out in this paper, that this map represents two separate stages, one of which is partly represented by a hiatus in the sedimentary column in the Ohio basin and was therefore marked by a temporary emergence of that region, while the country to the east was invaded from the southeast. This invasion is that of the Zygospira erratica fauna.

Other than faunal evidence. The paleontologic evidence furnished in the preceding chapters indicates that, in agreement with the view expressed by Ulrich (1911, p. 510), the faunal changes in New York, from the Utica to the Lorraine run, in the whole, parallel to those recognized in the Cincinnatian of Ohio; and further that in the earlier stages the open sea reached western and central New York from the southwest and in the later ones also from the south. For the most part, then, central and north central New York formed a part of the eastern margin of the wide and shallow seas that extended from the Gulf of Mexico northward to the region of the Great Lakes and beyond into Ontario and Quebec.

In the preceding Utica and Deer River stages, however, the conditions were different, in so far as the Utica sea was inhabited by a north Atlantic fauna, invading somewhere from the northern Atlantic through the present Appalachian region and spreading thence westward, while the Deer River shale seems to be connected with the Gloucester shale of Canada, which represents an invasion from the northeast along the St Lawrence basin.

It was further recognized that, notwithstanding the distinct parallelism of the stages in New York and Ohio, there are developed sufficient local faunal differences in New York to suggest the existence of minor barriers and basins about the Adirondack isle in the Eden and early Maysville seas, similar in character to those recognized by Ulrich and Ruedemann (Ruedemann, 1912, diagram facing p. 69) for the Trenton time. Foerste (1916) has already emphasized the imperfect condition of the Eden section in Ontario due to incomplete invasion, and further pointed to the faunal differences between the Pulaski of Quebec and Ontario east and the corresponding beds of Ontario west, as indicating the effectiveness of the Frontenac axis, extending northwest of the Adirondack massif, and that so often before had made its influence felt.

We have already noted the somewhat different faunal aspect of the Indian Ladder arm of the middle Eden sea; and in the preceding chapter the contrast between the Whetstone Gulf and Pulaski formations of New York so far as their faunal relations with the Ohio basin are concerned, have been discussed, and the close relationship of the Whetstone Gulf faunas with the Eden faunas on one hand, and of the Pulaski faunas with those of the Quebec and Allegheny regions on the other pointed out.

It now remains to compare with these conclusions from the study of the faunas, the evidence from the stratigraphic relations and the lithology of the beds. The latter falls naturally into two groups, namely, the evidence from the general succession of types of sediment in the Cincinnatian and that from the lithology of the individual members of the formations.

The cycle of deposition from limestone through black shale to shale and sandstone, represented by the Trenton, Utica and Lorraine groups has long been noted, and likewise the extension of the sequence of these lithologic units from the eastern Appalachian folds to western Kentucky (see Ulrich 1911, p. 525). As this sequence of lithologic units over this wide area is in full accordance with the faunal evidence, it is wholly legitimate to infer that similar conditions existed at the same time throughout the greater part of these successive epicontinental seas.

At the same time, the faunal evidence afforded by the New York rocks has shown that in this eastern marginal region some of the changes in lithic characters took place in advance of those farther west. Thus it has been recognized (Ruedemann, 1912) that while the limestone deposition of the clear sea of the middle Trenton Prasopora-stage was still taking place in the Trenton Falls region, farther east the black shale of the Canajoharie beds was already deposited, and still farther east and nearer the shore the alternating sands and shales of the Schenectady formation, and in a yet more easterly basin, those of the Snake Hill beds, were formed. The black shale transgresses westward upon the limestone, the last stage of the black shale reaching even as far west as western Kentucky (Ulrich 1911, p. 521). Going northward around the Adirondacks into the Black river valley, we find the limestone-making conditions even persisting, with the Cobourg limestone, beyond Trenton time as represented by the Trenton section, and a black shale invasion of later Utica time taking place from the north (Deer River shale), while the final stage of Utica time (Atwater Creek shale) is marked by black and gray shales.

In perfectly parallel fashion with the Trenton-Utica change the deposition of rocks of Frankfort and Lorraine aspect, that is, of alternating gray shale and sandstone began already in middle Trenton time in an eastern trough in New York that was still inundated, with the Schenectady beds; it transgressed westward with the Frankfort shale, and again in the Black river valley it does not become distinct until Economy or lower Whetstone gulf time, thence to persist throughout Lorraine time (see diagram p. 60).

Lorraine rocks. The Lorraine beds consist of predominant gray shales and intercalated thin sandstone layers in the lower or Whetstone Gulf division and of like shales alternating with heavy sandstone beds, many of which have a calcareous matrix, and of thinner limestone bands in the upper or Pulaski division.

Similar but still more rapid alternations of shale and limestone prevail in the Eden and Maysville formations of the Ohio basin. Several explanations have been advanced for these interminable alternations. The prevailing view is that they indicate a continual slow oscillation of the sea level which brought the bottom under the influence of varying currents and different conditions favorable to organic life.

A different explanation has been attempted by Cumings (1908, p. 680).

This author would recognize oscillation as cause for the lithologic changes only in the case of some of the larger oscillations as from predominant shale in the Eden to predominant limestone in the Maysville, but would look to climatic rather than to epeirogenic changes. By assuming that the change from impure limestone to calcareous shale is not necessarily very great and that the lime-secreting organisms, especially the bryozoans, brachiopods etc., are very sensitive to even a small influx of mud, it is inferred that more or less definite variations of longer period, in the amount of rainfall, such, for example, as the 11-year and the 36-year cycle, could very well control by the greater or smaller amount of land wash which they bring into the sea, the material that is deposited, a greater amount of land wash shutting out the lime-secreting animals and producing shale, while a comparatively rainless period would furnish but little terrigenous material and as a corollary a luxurious growth of lime-secreting animals, that would produce the limestone beds.

Another cause of the interleaving of calcareous and terrigenous sediments, is seen by Cumings, in the shifting position and strength of currents, especially shore currents, undertow, and tidal currents, since it is these currents that are chiefly instrumental in distributing the sediments to various parts of the sea bottom. The rate and amount of change of shore currents and undertow are dependent upon the varying strength of the wind, while the shifting of the position and the direction of currents is ordinarily due to changes in the contour of the coast line, brought about by erosion and deposition along the coast; but where the wind is variable in direction there is also a continual shifting of the position and direction of shore currents from this cause. All these factors, or in other words the well-known processes that are going on on any sea bottom, not too deep or too far removed from the land, are, according to Cumings, competent to have caused the multitude of smaller alternations.

Observations made by Walther (1919, p. 60, 67) in the Gulf of Naples show how a profound faunal and lithologic change may be produced at the bottom of the sea by a slight difference in relative depth. In the Gulf of Naples the bottom is a muddy plain, about 85 m. deep. On this plain live only 142 species as contrasted to 1120 species found in the gulf. Ten of these mud facies forms occur only attached to foreign bodies, sunk into the mud, 70 species are occasional stragglers from the nearby limesand facies and only 62 species or 1/20 of the gulf fauna are indigenous to the mud facies. Above the plain there rises up to 45 m. the ruin of a volcano, forming a submarine bank, two kilometers long and known as the pigeon-bank. This slight elevation over the mud plain is covered with rock, hard sand and calcareous algae and supports 360 species. Three hundred and ten of these have hard integuments and could be preserved as fossils, while only 45 of the mud facies could be preserved, and only 14 of these are common to both and could serve as index fossils.

This case seems to show distinctly how slight, frequent, local oscillations could bring certain regions for a time under the influence of the unfavorable mud facies and at other times under that of the calcareous sand facies which results from abundant life in places that are protected from the inwash of mud.

How rapid the growth of a calcareous lens resulting from the temporary elevation of a part of the muddy sea bottom may be, is also shown in the case of the "Pigeon-bank"; for Walther found the bank covered with richly foraminiferous shell sand, resulting from the breaking up of mollusk shells by crustaceans, but 25 years later the entire bank was so thickly grown over with calcareous algae, that the shell sand could not be reached.

The factor of slight oscillation illustrated by Walther's observations would seem competent to explain many of the abrupt changes from shale to limestone bands; in other cases the variation in amount of land wash due to climatic changes, adduced by Cumings, may have had a controlling influence.

The same factors seem competent to explain the manifold alternations in our Lorraine beds, with the qualification, however, that owing to the presence of more highly elevated lands in the east, and the greater nearness of the coast the lime-secreting animals but rarely experienced congenial conditions, especially so in the Whetstone Gulf formation, where but few thin limestone bands are developed, while the near coast and highland furnished an abundant supply of coarse and less chemically disintegrated detritus.

A significant observation in this connection is that the sandstone bands in the Whetstone Gulf formation, especially in the upper part, as in Wood creek station 15, and likewise those in the Pulaski division, are dark gray when fresh, but weathered have a rusty color and are full of limonite specks. Fresh portions of this sandstone, under the microscope, are seen to contain a considerable admixture of grains of magnetic iron, fresh feldspar and mica; a combination that clearly points to the granite of the nearby Adirondacks as the source of the material, and at the same time suggests a rapid physical disintegration of the granite and climatic conditions that were not too favorable to a rapid chemical disintegration, namely, a fairly dry climate. It is probable that some of this material was directly derived from the coast of Adirondackia.

A further interesting observation in the Lorraine beds is that the graptolites which here occur only at rather long intervals are, except the basal beds, not found in black shale bands, as in the similar Normanskill and Schenectady beds, but on thin coarse sandstone bands and are always arranged in parallel direction. These sandstone bands are hence clearly the result of sudden incursions of sand by strong current action, probably unusual strong undertow due to severe storms.

Still stronger current action is indicated by shell heaps on a cleanly-swept sea floor. Such are found at Pulaski below the railroad bridge on top of a thick sandstone bed with wide ripple-marks (see plate 4). Here the currents were powerful enough to pile the shells of Rafinesquina into compact masses, 2 feet in diameter, and to form on other beds lenticular masses of bryozoans, crinoid columnals and brachiopods. Wide symmetric ripple-mark and crescent-shaped ridges, 1½ feet high, indicate the strength of storms that swept the sea at times, and their prevailing north-northeast direction points to frequent west winds.

A perusal of the faunal lists shows clearly that there is no distinct faunal break in the Whetstone Gulf beds, but rather a gradual disappearance of the older forms and a corresponding gradual arrival of new species, many of which are close relatives of the vanishing forms. It is doubtful whether more complete faunal lists would materially alter this aspect of the life of the Whetstone Gulf formation. Likewise there is no distinct lithologic break observable anywhere in the Whetstone Gulf formation, for it persists as a rather uniform series of alternating shales and thin sandstone beds.

The Pulaski beds are in so far lithologically different from the Whetstone Gulf beds as the calcareous, rusty brown-weathering sandstones characteristic of this formation form thick banks, and this series of thicker beds begins with a noticeable abruptness, although there are similar yet thinner beds scattered through the upper Whetstone Gulf formation. In the uppermost Pulaski the gray noncalcareous sandstone intercalations begin to predominate until at last, by slow gradation, the uniform Oswego or Salmon River sandstone is reached.

Cumings (1908, p. 684) has inferred that " while the aspect of the Cincinnati faunas is a constantly changing one, the changes seem to be due more to a rather quiet evolution within the area of the epicontinental sea occupied by these faunas, than to any pronounced irruptions of species from other provinces, if one excepts the influx of outsiders in the Richmond."

Ulrich has also pointed to the persistence of the lithologic characters over wide areas. According to Ulrich (1911, p. 521) the characteristic greenish or bluish shale of the Eden is " unmistakably recognizable in outcrops and in deep wells from Kentucky to central New York and in the Appalachian shale formations from Pennsylvania to Tennessee." It is then probable that the wide and shallow epicontinental sea persisted throughout most of Eden time without material change of its expanse and character.

There were nevertheless sufficient changes in the expanse of the Eden sea to disturb the quiet evolution so that distinct horizons can be recognized over large areas, and, as in the case of the McMicken stage, the sea withdrew entirely from a large portion of its former territory.

In the Maysville-Pulaski period the changes seem to have been more marked and impressive. While the Maysville sea first advanced from the southwest, then between Fairview and MacMillan time withdrew again, while the Pulaski invasion took place from the southeast, a second invading sea returned from the southwest that met and united in the closing stages of the Ordovician with the southeastern Atlantic invasion. In Oswego time, sandy shallows developed over New York that separated the Quebec embayment from the

Allegheny basin and finally being lifted above sea level brought Ordovician deposition to a close in this region.

Neither was the life of the Maysville-Pulaski sea marked by impressive changes. The most important change in this sea was probably the opening of an eastern waterway to the Atlantic basin, as already represented in Ulrich's chart, whereby the Atlantic elements that are observable in the Pulaski faunas in Quebec, eastern Ontario and New York were admitted.

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